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SOIL
CONSERVATION
SERVICE

REVIEW
SURVEY
REPORT

WASHITA RIVER
WATERSHED
OKLAHOMA
AND
TEXAS

PROGRAM FOR
RUNOFF AND
WATERFLOW
RETARDATION
AND
SOIL EROSION
PREVENTION

REVIEW SURVEY REPORT

WASHITA RIVER WATERSHED

OKLAHOMA AND TEXAS

PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U. S. DEPARTMENT OF AGRICULTURE
NOVEMBER 1951

AGR-SCS FT WORTH,TEX. 11-51

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UNITED STATES DEPARTMENT OF AGRICULTURE

3 Review Survey Report

WASHITA RIVER WATERSHED, OKLAHOMA AND TEXAS, + 3a

3a Program for Runoff and Waterflow Retardation and Soil Erosion Prevention //

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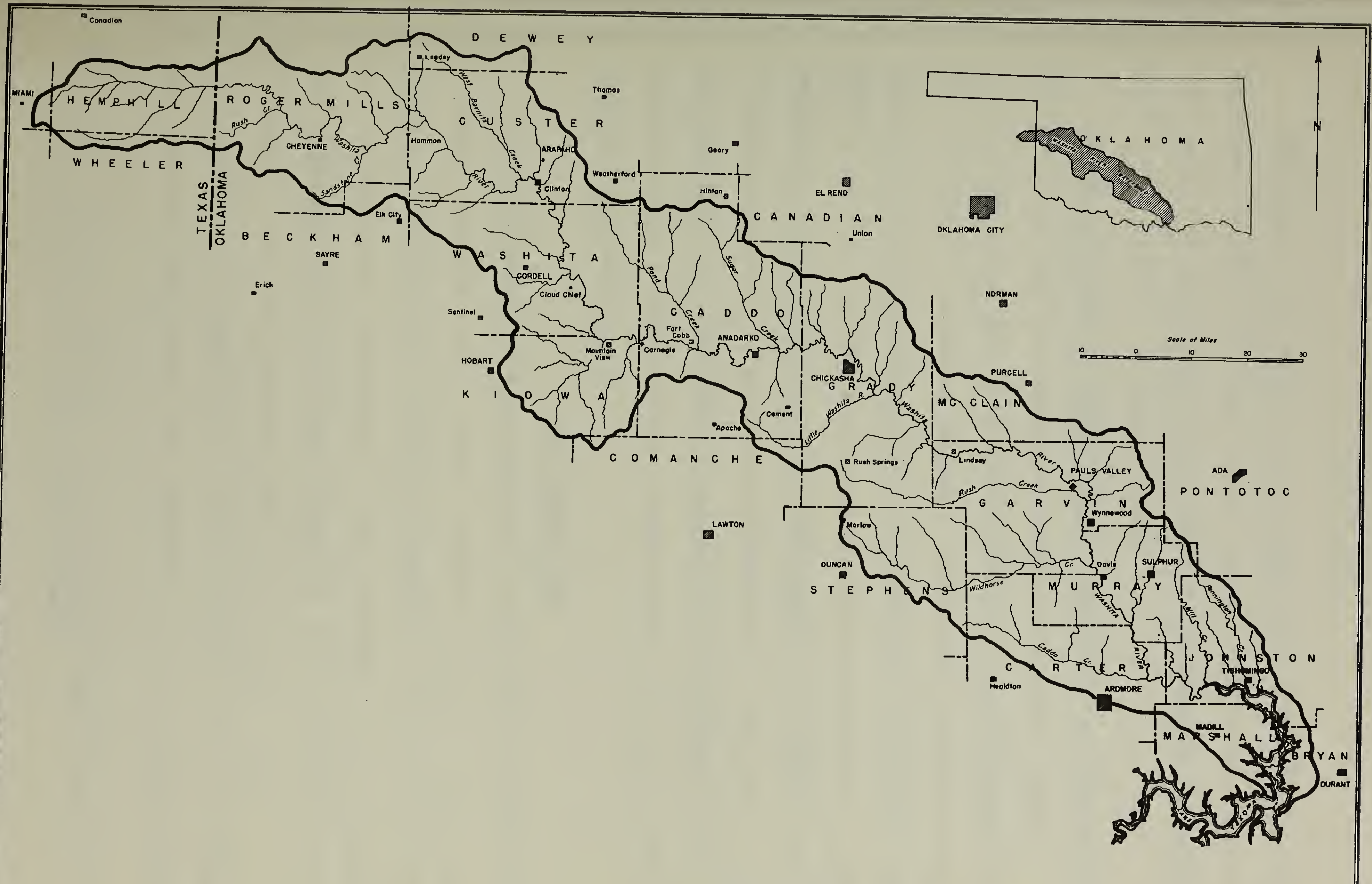
Prepared By
U.S. SOIL CONSERVATION SERVICE, //

C O N T E N T S



WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

H.H. BENNETT-CHIEF

REGION 4 DIRECTOR-LOUIS P. MERRILL

REFERENCE

CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

COMPILED — TRACED — CHECKED — DATE

AGR-SCS-FORT WORTH, TEX JUNE, 1951

Base 4-N-7950

INTRODUCTION

Authority. This review of the survey report of the Washita River Watershed, Oklahoma and Texas, House Document No. 275, 78th Congress, 1st Session, was authorized by resolution of the Committee on Public Works of the Senate on January 28, 1949.

Purpose and Scope of Review Report. The purpose of this review report is to present information concerning the changes in physical and economic conditions which have occurred since the original survey was made, to describe a modified program of runoff and waterflow retardation and soil erosion prevention for the watershed of the Washita River, Oklahoma and Texas, which, when authorized, will supersede the program outlined in House Document No. 275; 78th Congress, 1st Session, and authorized by the Flood Control Act of December 22, 1944, and to present recommendations for installing and maintaining the modified program, together with an analysis of its cost and benefit. The area considered contains 7,961 square miles.

RECOMMENDATIONS

It is recommended that the Secretary of Agriculture be authorized to install, during a 15-year period, a modified program of runoff and waterflow retardation and soil erosion prevention for the Washita River Watershed in Oklahoma and Texas, as herein described, at an estimated cost of $59,147,000 to the Federal Government, at an estimated cost of $626,000 to other public agencies, and at an estimated cost of $14,292,000 or its equivalent 1/ to local interests, making an estimated total cost of $74,065,000 for the installation of the modified program.

1/ Labor, materials, equipment, land, easements, rights-of-way, and other contributions in lieu of cash payments.

When fully installed the modified program will be operated and maintained at an estimated annual cost of $114,000 to the Federal Government and at an estimated annual cost of $4,501,000 or its equivalent to local interests, making a total estimated annual cost of $4,615,000. Of the amount to be expended by local interests, it is expected that $4,155,000 or its equivalent will be expended by landowners and operators for operating and maintaining a more intensive and profitable system of conservation farming, which is expected to result in an additional annual return of $7,737,000, and that $346,000 will be expended by a local agency or agencies acceptable to the Secretary of Agriculture for operating and maintaining those installations which are not considered a part of farm and ranch operations.

The modified program described herein will accomplish greater reductions in annual flood and erosion damages than the program authorized in House Document No. 275. The estimated cost to the Federal Government of the modified program includes the amounts which have been appropriated and allotted for works of improvement in carrying out the program outlined in House Document No. 275.

The modified program herein recommended includes the intensification, acceleration, or adaptation of certain activities under the current programs of Federal Agencies in the watershed, and additional measures not now regularly carried out in such programs, all of which are necessary to complete a balanced runoff and waterflow retardation and erosion control program for the watershed. It is recommended that the Secretary of Agriculture be authorized to carry out all of this program except the part which is proposed for installation on land under the jurisdiction of a Federal agency other than the Department of

Agriculture. It is further recommended that the head of such other Federal agency be authorized to carry out the part of the program which is proposed for installation on land under the jurisdiction of such agency. The extent to which the work recommended in this modified program for which the Secretary of Agriculture is to be responsible will be carried out under the Flood Control Act as requested herein or under other authorities will be considered by the Secretary in requesting appropriations for the prosecution of the program. Current activities of the Department in this watershed as authorized by the 1944 Flood Control Act are included in the modified program herein recommended. Although other current activities of Federal agencies in the watershed which are primarily related to the objectives of the Flood Control Act are not included in the modified program herein specifically recommended, the modified program is based on the continuation of such activities at least at their present level. The extent to which the practices and measures included in the recommended modified program may be carried out by the acceleration, intensification, or adaptation of certain activities under the current programs of Federal agencies in the watershed will be taken into account in requesting appropriations for the prosecution of the modified program.

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The measures which will accomplish the desired objective of reducing floodwater and sediment damage and conserving soil and water resources are as follows: construction of terraces and field diversions, cover cropping, contour cultivation, strip cropping, liming and fertilizing of grasses and legumes, seeding and fencing of grassland, stabilization of gullies, fire protection of range and forest lands, land acquisition, management and development of acquired land, construction and vegetating

of farm and group waterways, construction of grade stabilizing structures, and construction of floodwater retarding structures and associated drop inlets, floodways and diversions.

Technical services will be made available for planning and applying the necessary land use adjustments, for planning and applying land treatment measures on farm and ranch lands and for integrating the measures included in the recommended modified program. Educational assistance and direct aids will be provided to facilitate the installation of the recommended modified program.

The Secretary of Agriculture may construct such buildings and other improvements as are needed to carry out the measures included in the recommended modified program.

The Secretary of Agriculture may make such modifications or substitutions of the measures described in this report as may be deemed advisable on account of changed physical or economic conditions or improved techniques, whenever he determines that such action will be in furtherance of the objectives of the recommended modified program.

The authority of the Secretary of Agriculture to prosecute the recommended modified program shall be supplemental to all other authority vested in him, and nothing in this report shall be construed to limit the exercise of powers heretofore or hereafter conferred on him by law to carry out any of the measures described herein or any other measures that are similar or related to the measures described herein.

It is estimated that the recommended modified program will yield an average annual flood control benefit of $4,296,000 1/. In addition

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1/ 1949 Prices.

to this flood control benefit, an estimated average annual benefit of $7,737,000 1/ from conservation farming and ranching will accrue to landowners and operators in the watershed.

The ratio of the estimated average annual benefit to the estimated average annual value of the total cost of the recommended modified program is 1.72 to 1. 2/

It is anticipated that the recommended measures will be installed under cooperative arrangements with soil conservation districts, State and local governments, or other agencies acceptable to the Secretary of Agriculture.

DESCRIPTION OF THE WATERSHED

From its source in the Texas Panhandle, the Washita River flows approximately 650 miles in a southeasterly direction diagonally across the western half of Oklahoma. Near Tishomingo, Oklahoma it empties into Lake Texoma, a flood control and power reservoir impounded by a dam on the Red River immediately below the junction of the Washita and Red Rivers. The Washita River drains an area of 7,490 square miles in Oklahoma and 471 square miles in Texas.

The Washita River Watershed is a long, narrow watershed with numerous side tributaries entering along its entire length. The principal tributaries are Barnitz Creek, Rainy Mountain Creek, Pond Creek, Sugar Creek, Little Washita River, Rush Creek, Wildhorse Creek, and Caddo Creek.

1/ 1949 Prices.

2/ Based on future price and cost levels assumed to prevail under an intermediate level of employment.

The topography of the watershed is generally rolling. A few small areas of level lands are found along the watershed divides but most of the level lands are in the flood plain. Rough mountainous lands are found only in the granitic uplift areas. The elevation of the watershed ranges from 500 feet mean sea level at the mouth of the Washita River to about 3,000 feet near its source in Roberts County, Texas.

The economy of the watershed is rural. Since settlement began in the Texas headwaters in 1870, farming and ranching have predominated in the area. Cotton gins, cottonseed oil mills, alfalfa mills, elevators, stone crushers, granite quarries, oil fields, oil refineries and broom factories are important industrial establishments in the watershed.

Approximately 48 percent of the watershed is in crops, 36 percent in open grassland, 11 percent is blackjack-post oak savanna (grazing land), one percent is woodland, and four percent is in miscellaneous uses. The principal crops are wheat, cotton, grain sorghum, alfalfa, oats and corn.

In 1940 the total population was 221,000 of which 75 percent was classified as rural. From 1930 to 1940 the rural population declined 14 percent. During this same period, though there was a small increase in the urban population, the total population declined nine percent.

The average annual precipitation in the watershed ranges from 22 inches in the extreme western area to about 38 inches near the mouth of the river.

FLOOD PROBLEMS

Approximately 265,000 acres on the tributaries and 112,000 acres on the main stem of the Washita River are subject to flooding. The

tributaries have a higher frequency of flooding than the main stem, some areas averaging as high as nine floods per year.

The highest frequency of flooding on any reach of the main stem is slightly in excess of two floods a year. Damaging floods occur most frequently during April, May, and June, at which time serious damage is done to growing crops. Fall floods occur less frequently but often damage mature crops.

Two general types of storms produce flooding in the watershed. Local storms covering about 100 to 400 square miles result in floods on tributaries. Floods on the main stem resulting from these local storms are usually of short duration and affect only a small portion of the main stem. General storms, covering large portions of the watershed, result in severe flooding on the main stem of the river as well as on the larger tributaries.

Of the total average annual floodwater and sediment damage in the watershed approximately 75 percent occurs on tributaries of the Washita River. This is due to the high frequency of flooding and large aggregate area subject to flooding on the tributaries.

Crop and pasture damage constitutes 58 percent of all floodwater and sediment damage in the watershed. Approximately 89 percent of the crop and pasture damage occurs on bottomland areas of the tributaries and 11 percent on the main stem flood plain.

Approximately 265,000 acres of valley land have been damaged by sediment deposition, scouring, and streambank erosion. The degree of damage ranges from slight, where a small capital outlay will restore productivity, to a total loss of productive capacity. In addition to

this land damage, deposition of sediment has reduced channel capacities, thereby impairing drainage and increasing the frequency of flooding.

The annual rate of reservoir storage capacity loss by sedimentation is a serious problem in a major portion of the watershed. The useful capacity of several municipal water supply reservoirs is being rapidly depleted by a continuing accumulation of sediment. Annual sediment accumulation per square mile of drainage area ranges from 0.5 acre-foot in Veterans Lake near Sulphur to 3.95 acre-feet in Lake Duncan, a water supply reservoir for Duncan, Oklahoma. Based on a 6.2 year period of record the Washita River Watershed annually contributes to the sedimentation of Lake Texoma approximately 1.29 acre-feet of sediment per square mile of drainage area. This amounts to an annual capacity loss of 9,800 acre-feet.

Other damages which were considered but not evaluated in monetary terms include insecurity of income, disruption of public service, damage to recreation and wildlife, and costs of relief and sanitation.

Table 1 lists the monetary evaluation of the average annual floodwater and sediment damages in the Washita River Watershed.

RELATED ACTIVITIES

As authorized in the 1950 Flood Control Act and by subsequent Presidential directives, an Inter-Agency Committee has been organized to undertake a comprehensive investigation of the Arkansas-White-Red Basins and to develop integrated plans of improvement "for navigation, flood control, domestic and municipal water supplies, reclamation and irrigation, development and utilization of hydro-electric power, conservation of soil, forest and fish and wildlife resources, and other beneficial

TABLE 1

ESTIMATED AVERAGE ANNUAL MONETARY DAMAGE

Washita River Watershed

Type of Damage		Average Annual Damage (1949 Prices) (Dollars)
FLOODWATER DAMAGE		
Agricultural and Nonagricultural		
Crops and Pasture	3,137,000	
Other Agricultural	634,000	
Nonagricultural	582,000	
Subtotal		4,353,000
Land		
Flood Plain Scour	109,000	
Streambank Erosion	75,000	
Subtotal		184,000
SEDIMENT DAMAGE		
Deposition of Infertile Overwash	131,000	
Sedimentation of Reservoirs	202,000	
Subtotal		333,000
INDIRECT DAMAGE		664,000
TOTAL AVERAGE ANNUAL DAMAGE		5,534,000

development and utilization of water resources including consideration of recreational uses, salinity and sediment control and pollution abatement . . .". This committee is composed of a representative of the Corps of Engineers as chairman, representatives of the Department of the Interior, Department of Agriculture, Department of Commerce, Federal Power Commission, the Federal Security Agency, and the governors of the states of Arkansas, Louisiana, Oklahoma, Texas, New Mexico, Kansas and Missouri. It is contemplated that the investigation and preparation of the report will be completed June 30, 1954.

In his memorandum of February 8, 1951 to H. H. Bennett, Chief of the Soil Conservation Service, Assistant Secretary of Agriculture K. T. Hutchinson stated that in view of the urgency of the Resolution of the Senate Public Works Committee authorizing a resurvey of the Washita River Watershed, it is desirable that the review report be processed at the earliest practicable date. Since the report of the comprehensive investigation of the Arkansas-White-Red Basins is not scheduled for completion until June 30, 1954, in order to avoid undue delay it is necessary that this review of the Survey Report, Watershed of the Washita River (Oklahoma and Texas), House Document No. 275, 78th Congress, 1st Session, be submitted for separate consideration.

In developing this report close liaison has been maintained with the Arkansas-White-Red Basins Inter-Agency Committee and with the USDA Field Committee for those Basins in order that the modified program recommended herein might be integrated as fully as possible with the proposed works of improvement being considered by other Federal and State agencies. However, since the report for these Basins is

scheduled for June 30, 1954, complete coordination of the modified program recommended herein with the works of improvement recommended in the final plan for the Basins will not be possible until after that date.

In the comprehensive Basins investigations the Corps of Engineers and the Bureau of Reclamation are studying the feasibility of constructing a system of major reservoirs on the main stem of the Washita River and several of its tributaries for flood control, irrigation, power development and allied purposes. Since it is not known at this time how many of these structures, if any, may be recommended in the Basins report, they have not been considered in the development of the modified program recommended herein. However, since work plans are prepared and construction activities are undertaken by individual tributary watersheds under the current operations program, thorough integration of the modified program recommended herein with the final Basins plan can be readily achieved.

The Department of Agriculture, through its several agencies and in cooperation with State and local agencies, is currently assisting owners and operators of farm and ranch lands in the application of measures which are deemed of primary importance to the objectives of the Flood Control Act. Measures being installed on cropland include terraces, field diversions, establishment of farm and group waterways, grade stabilizing and waterflow or erosion control structures, conservation crop rotations, cover crops, strip crops, stubble mulch tillage, and contour farming. On grassland or on land being converted from cropland to grassland the measures are grass seeding, the application of fertilizer for adequate growth and establishment of cover, proper management of grazing,

fire protection and the control of brush and weeds. The Department of Agriculture is expending approximately $1,443,000 annually to assist in the application of these measures on the lands of the watershed.

The Department of the Interior through the Bureau of Indian Affairs is assisting owners and operators of restricted Indian lands in the application of soil and moisture conservation measures similar to those being installed on private lands with the assistance of the Department of Agriculture.

The State of Oklahoma, through its Division of Forestry, is currently assisting local organizations of landowners in providing fire protection to 71,370 acres of land in Marshall and Johnston counties which has a tree cover of blackjack and post oak.

The States of Oklahoma and Texas operate through several of their departments and institutions to provide valuable conservation services to farmers, ranchers, municipalities and industries. This includes research (experiment stations) and the dissemination of research findings, educational activities and services.

The Oklahoma State Planning and Resources Board has investigated, planned, and recommended the installation of 26 small flood control dams, including estimated capacities, costs, and benefits. The plan includes one reservoir on the main stem in its upper reaches and 25 reservoirs on tributary streams.

Several associations, with membership composed of local farm and ranch owners and operators, business and professional men, and other interested parties, have been organized in the watershed to further the development and conservation of water resources. Of these associations, the Washita Valley Flood Control Association is one of the more active at the present time.

RECOMMENDED MODIFIED PROGRAM

The recommended modified program of runoff and waterflow retardation and soil-erosion prevention includes the following measures:

1. Construction of approximately 33,200 miles of terraces. These will be constructed on sloping farm lands to conduct excess rainfall at non-erosive velocities to protected outlets or waterways. This measure will reduce the amount of sediment carried to streams by decreasing the length of unbroken slope. All terraced land will be cultivated parallel to the terraces.

2. Construction of approximately 2,580 miles of field diversions. These graded channels will be designed to divert runoff away from severely eroded or local high-damage areas. Their use will assist in the establishment of grassland and in the protection of cropland measures to be used for cover protection and erosion control.

3. Establishment of cover crops on approximately 1,065,000 acres of cropland. Cover crops will protect the soil from erosion and will increase the soil organic matter. These crops, used for green manure or as cash crops, will be grown in the normal cropping systems and will occupy approximately thirty to thirty-five percent of the cropland each year. 43,900

4. Establishment of a system of contour farming on 10,900 acres of land not requiring terraces. Contour farming will reduce runoff and erosion by holding the water on the land.

5. Establishment of strip cropping on 105,300 acres of cropland seriously affected by wind erosion in the western portion of

the watershed. Strip crops reduce soil loss from wind erosion and increase the organic matter in the soil, thereby increasing its water-holding capacity.

6. Application of lime to grasses and legumes on 112,100 acres of land. The application of lime makes possible better growth of legumes which fix the nitrogen essential to vigorous root development. It improves the tilth of the soil, thereby increasing the water-holding capacity and reducing runoff and erosion.
7. Application of fertilizer to 541,300 acres of grasses and legumes. Fertilizer will increase root growth and improve the vegetative cover. The resulting improvement in watershed conditions will reduce erosion and runoff.
8. Seeding of adapted grasses and legumes on approximately 234,700 acres of cropland, idle land and overgrazed grassland. The grass cover will protect the soil from continued erosion and will increase infiltration of rainfall.
9. Building of 1,140 miles of fencing to protect land converted from cropland to grassland. Fencing will protect the new grassland from grazing and allow it to become established thoroughly before receiving normal use.
10. Stabilization of approximately 86,500 acres of gullied land for waterflow and sediment control. Revegetation, shaping, drop structures and small earthfill dams, to reduce the uncontrolled gradient of channels, arrest head cutting and reduce the rate of discharge of runoff by natural or

artificial controls, will be used to control land damage and the amount of sediment resulting from erosion of the channels.

11. Improved fire protection for 421,000 acres of private woodland and blackjack-post oak savanna. This measure will increase infiltration and water-holding capacity of the soil, improve cover conditions, and materially reduce erosion and runoff.

12. Acquisition of 328,100 acres of severely eroded watershed land that is contributing heavily to flood flows and sediment output. Because of the poor quality of the land and the low returns derived from it, none of the landowners is able to treat and manage this land in accordance with its needs. Only through public acquisition can such areas be improved and managed for watershed protection.

13. Development and management of 328,100 acres of acquired land. The development, improvement and management of acquired land will be aimed at improving watershed conditions through the establishment of permanent grassland vegetation on all acquired land.

14. Shaping and stabilizing by vegetative control approximately 2,560 miles of farm and group waterways to reduce the amount of sediment and gullying resulting from the uncontrolled discharge of terraces. Broad vegetated strips with minimum shaping will be used to convey the runoff from the terraced fields safely down the slope to stable grade.

15. Construction of 3.600 grade stabilizing structures in connection with the land treatment measures. These structures will aid in the stabilization of waterways by reducing the

grades of the channels, and will arrest head cutting of gullies. They will also facilitate the establishment of the land treatment measures.

16. Construction of 652 floodwater retarding structures and their associated appurtenances. These structures and appurtenances, by providing temporary storage of floodwaters from approximately 39 percent of the watershed area, will reduce flood peak discharges in the flood plains below the structures.

Technical services will be made available for planning and applying the necessary land use adjustments and land treatment measures on the farms and ranches, and for integrating these measures with the other measures included in the recommended modified program. Educational assistance will be provided to facilitate the installation of the recommended modified program. Non-Federal public agencies will bear approximately one-half the cost of educational assistance. Technical services, educational assistance, and other aids provided under this program will be directed toward furthering the specific objectives of floodwater and sediment damage reduction and will be fitted as to method and synchronization into subwatershed operations activities.

Provision will be made in selected segments of subwatersheds for the measurement of precipitation, runoff, groundwater recharge, and sediment loads of streams, to facilitate application of the recommended modified program.

COST OF RECOMMENDED MODIFIED PROGRAM

The estimated cost of installing the recommended modified program in the Washita River Watershed is shown in table 2. Of this cost it is

Table 2

ESTIMATED COST OF INSTALLING THE RECOMMENDED MODIFIED PROGRAM

Washita River Watershed

Measure	Unit	Quantity	Cost (1949 Prices) (Dollars)
Terraces	Miles	33,200	5,271,000
Field Diversions	Miles	2,580	778,000
Cover Crops	Acres	1,065,200	7,303,000
Contour Cultivation	Acres	10,900	7,000
Strip Cropping	Acres	105,300	98,000
Liming Grasses and Legumes	Acres	112,100	959,000
Fertilizing Grasses and Legumes	Acres	541,300	5,389,000
Seeding Grassland	Acres	234,700	1,736,000
Fencing New Grassland	Miles	1,140	648,000
Gully Control	Acres	86,500	668,000
Improved Fire Protection	Acres	421,000	102,000
Public Acquisition	Acres	328,100	3,935,000
Development of Acquired Land	Acres	328,100	2,528,000
Farm and Group Waterways	Miles	2,560	1,022,000
Grade Stabilizing Structures	Each	3,600	2,874,000
Floodwater Retarding Structures and Appurtenances	Each	652	40,746,000 57%
Total			74,065,000 1/

4.4

296 260 ~~000~~
196 160

1/ Of this amount 4.4 percent is for technical services, hydrologic studies to facilitate program installation, administration of direct aids and educational assistance. Non-Federal public agencies will bear approximately one-half the cost of educational assistance, and one-fourth the cost of fire protection.

$3,258,860

59147000
3258860
$55,888,140 available for direct aids and construction.

estimated that the Federal Government will expend $59,147,000, other public agencies will expend $626,000 and private interests will contribute $14,292,000.

The recommended modified program will be operated and maintained at an estimated annual cost of $114,000 to the Federal Government and at an estimated annual cost of $4,501,000 or its equivalent to local interests, making a total estimated annual cost of $4,615,000. Of the amount to be expended by local interests, it is expected that $4,155,000 or its equivalent will be expended by landowners and operators for maintaining land treatment measures and for the increased cost of operating a more profitable system of conservation farming, and that $346,000 will be expended by a local agency or agencies acceptable to the Secretary of Agriculture for operating and maintaining those installations which are not considered a part of farm and ranch operations.

BENEFITS FROM THE RECOMMENDED MODIFIED PROGRAM

The recommended modified program will reduce floodwater and sediment damages and increase crop production. It is estimated that the program will reduce floodwater damage to crops, grassland, and other agricultural and nonagricultural property by approximately 64 percent, floodwater damage to land by approximately 35 percent, sediment damage by approximately 40 percent and indirect damage by approximately 63 percent. Other benefits will accrue from the more intensive use of flood plain lands made possible by the elimination of numerous small floods. Benefits in the form of increased crop and grassland yields will result from the installation of the land treatment portion of the program.

The full attainment of the benefit evaluated in this report is dependent upon the cooperation and support of farm owners and operators and local agencies in installing and maintaining the recommended practices and measures.

The estimated average annual monetary benefit resulting from the recommended modified program for the Washita River Watershed is shown in table 3.

In addition to the monetary benefit, there will be unevaluated benefits such as increased food and improved shelter for wild fowl and game animals, a greater population of fish as a result of clearer streams of more even flow, and improved recreational facilities.

COMPARISON OF BENEFIT AND COST

The ratio of the estimated average annual benefit to the estimated average annual value 1/ of the total cost of the recommended modified program is 1.72 to 1. The ratio has been computed on the basis of future price and cost levels assumed to prevail under an intermediate level of employment.

1/ Interest rates of 2.5 percent for public and 4 percent for private were used for conversion of capital costs to their annual equivalents.

TABLE 3

ESTIMATED AVERAGE ANNUAL MONETARY BENEFIT FROM

THE RECOMMENDED MODIFIED PROGRAM

Washita River Watershed

Source		Average Annual Benefit (1949 Prices) (Dollars)
REDUCTION IN FLOODWATER DAMAGE		
Agricultural and Nonagricultural		
Crops and Pasture	1,977,000	
Other Agricultural	419,000	
Nonagricultural	378,000	
Subtotal		2,774,000
Land		
Flood Plain Scour		63,000
REDUCTION IN SEDIMENT DAMAGE		
Deposition of Infertile Overwash	61,000	
Sedimentation of Reservoirs	72,000	
Subtotal		133,000
REDUCTION IN INDIRECT DAMAGE		416,000
INTENSIFIED USE OF FLOOD PLAIN LANDS		
Increased Income from the Land		910,000
CONSERVATION BENEFIT 1/		7,737,000
TOTAL AVERAGE ANNUAL BENEFIT		12,033,000

1/ The benefit which accrues to the owners and operators of the land on which the recommended modified program is installed.

REVIEW SURVEY REPORT

WASHITA RIVER WATERSHED

OKLAHOMA AND TEXAS

PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

(APPENDICES)

U. S. DEPARTMENT OF AGRICULTURE
NOVEMBER 1951

AGR-SCS FT WORTH,TEX. 11-51

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UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDICES

Review Survey Report

WASHITA RIVER WATERSHED, OKLAHOMA AND TEXAS

Program for Runoff and Waterflow Retardation and
Soil Erosion Prevention

Prepared by
SOIL CONSERVATION SERVICE

WASHITA RIVER WATERSHED

TABLE OF CONTENTS

TABLE OF CONTENTS

(Continued) Page

LIST OF TABLES

LIST OF TABLES

(Continued)

LIST OF FIGURES

APPENDIX I

PHYSICAL FACTORS

DESCRIPTION OF THE AREA

The Washita River rises in Roberts County, Texas, and flows easterly and southeasterly across the southwestern part of Oklahoma. It empties into Lake Texoma near Tishomingo in Johnston County, Oklahoma. The watershed of the Washita River is about 300 miles long, and 25 to 50 miles wide. It is essentially a long narrow watershed with numerous side tributaries entering it along its entire length. The total drainage area is 7,961 square miles (5,095,040 acres); 471 square miles are in Texas, and 7,490 square miles are in Oklahoma. Table 1 shows the area of the watershed by states and counties.

The principal tributaries entering the Washita are Barnitz Creek, Rainy Mountain Creek, Pond Creek, Sugar Creek, Little Washita River, Rush Creek, Wildhorse Creek and Caddo Creek.

The topography of the watershed is generally rolling. Some few areas of level lands are found along the watershed divides but most of the level lands are in the flood plain. Rough mountainous lands are found only in the granitic uplift areas. The elevation of the watershed ranges from 500 feet mean sea level at the mouth of the Washita to about 3,000 feet near its source in Roberts County, Texas.

PROBLEM AREAS IN SOIL CONSERVATION

The watershed was divided into seven problem areas in soil conservation (figure 1) in order to facilitate economic investigations involving farm organization, crops and crop yields, changes in land use, rate of soil loss, etc. One problem area in soil conservation was further divided into five sub-areas. Each problem area or sub-area is an

Table 1 - Area of the Watershed by States and Counties

Washita River Watershed

State and County	Total County Area 1/ (Acres)	Area in Watershed (Acres)	Percent of County
Oklahoma			
Beckham	580,480	26,419	4.6
Bryan	594,560	52,500	8.8
Caddo	816,640	642,302	78.7
Canadian	575,360	4,330	0.8
Carter	535,680	297,902	55.6
Comanche	698,880	20,832	3.0
Custer	640,640	457,305	71.4
Dewey	652,160	40,563	6.2
Garvin	520,960	493,488	94.8
Grady	701,440	530,676	75.7
Johnston	420,488	262,744	62.5
Kiowa	661,760	228,794	34.6
McClain	366,720	150,307	41.0
Marshall	269,440	123,313	45.8
Murray	273,920	270,419	98.7
Pontotoc	462,720	5,480	1.2
Roger Mills	729,600	505,116	69.2
Stephens	572,160	213,705	37.4
Washita	646,400	467,405	72.3
Totals		4,793,600	
Texas			
Hemphill	594,560	250,819	42.2
Roberts	588,800	11,776	2.0
Wheeler	592,000	38,845	6.6
Totals		301,440	
Total Watershed Area		5,095,040	

1/ Based on U. S. Census, 1940.

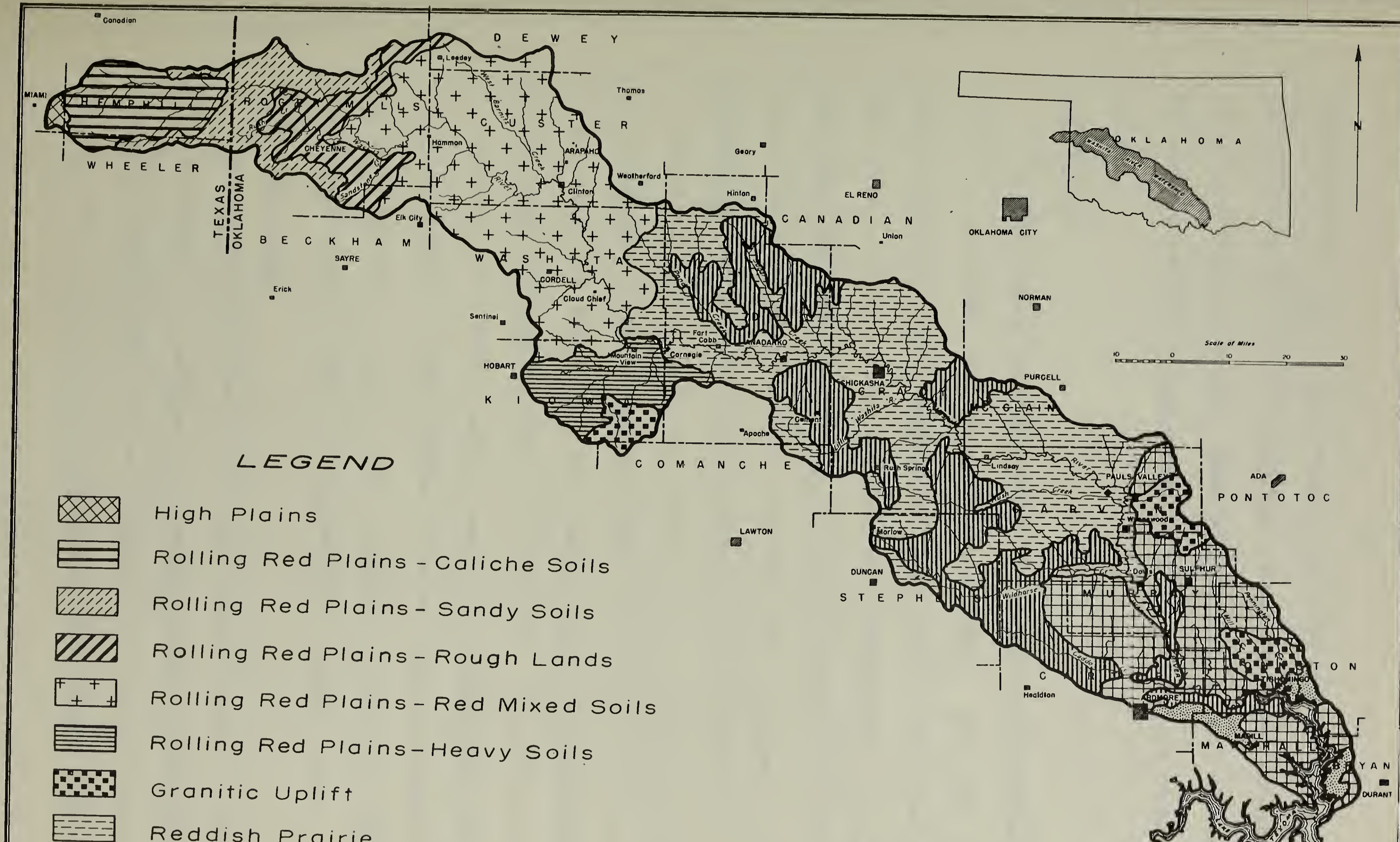

Figure 1

CONSERVATION PROBLEM AREAS

WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS

U.S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

H.H. BENNETT - CHIEF

REGION 4 DIRECTOR - LOUIS P. MERRILL

CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

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association of soil, slope, erosion and other conditions which is characterized by essentially uniform runoff, sediment output, and deterioration of soil resources. Each problem area in soil conservation or sub-area is readily recognizable. A brief description of these areas follows:

High Plains

The High Plains occupies only 5,777 acres on the extreme western tip of the watershed, all in the State of Texas. This area is characterized by smooth and level topography broken only by small depressions or playa lakes, and by shallow smooth-sloped drainageways. Most of the rainfall which does not find its way into the soil drains into the playa lakes; relatively small amounts of runoff leave the area in the shallow drainageways which drain eastward into the Rolling Red Plains.

The soils of this area are heavy in texture, deeply developed and have moderately high infiltration rates. The water-retention capacity of these soils is very high. Often wheat crops are made with moisture that has been retained from the preceding fall. The area is predominantly cultivated, with wheat, cotton, and grain sorghums the major crops.

Flood damages in this portion of the watershed are negligible. Some local flooding of small areas is caused by excessive rains, but water seldom stands on the land long enough to cause damage.

Rolling Red Plains

The Rolling Red Plains covers some 1,937,000 acres, or 38 percent, of the watershed. It extends from the High Plains on the western edge of Hemphill County, Texas, to an irregular line running north and south in the vicinity of the western boundary of Caddo County, Oklahoma.

Due to the complex nature of soils, land use, and topography in the Rolling Red Plains, it was necessary to make five subdivisions in order to properly classify this area into sub-areas which have essentially uniform runoff and sediment output. These subdivisions are discussed in the following section:

Rolling Red Plains, Caliche Soils Area: This area, covering about 213,000 acres in Hemphill County, Texas represents a transition from the High Plains to the Rolling Red Plains. The area is intricately dissected by numerous small drainageways, leaving only a small percentage of the area on topography smooth enough to permit cultivation. Shallow caliche soils, occupy about 75 percent of the area, and sandy soils with moderately heavy subsoils occupy the remainder. The caliche soils are shallow prairie soils, the surface soil averaging about five inches in depth. The parent material, a whitish limy caliche, normally occurs at depths of eight to ten inches. These soils are extremely porous, and absorb rainfall rapidly, therefore the runoff is not as great as would be expected from a hilly area.

About 80 percent of this area is used as range land whose native cover is principally of the short grass type. The remaining 20 percent is cultivated land devoted chiefly to small grains or grain sorghums.

Rolling Red Plains, Sandy Soils Area: This area occupies about 252,000 acres in Hemphill County, Texas, and Roger Mills County, Oklahoma. The topography is undulating to rolling except along the breaks of the Washita River, where it is rough and steep. The soils are predominantly deep sands of high infiltration rates. Runoff is practically negligible under normal rainfall conditions. However, in

periods of excessive rainfall, after the capacity of the soil to absorb water has been exhausted, runoff and erosion are extremely high. This accounts for much of the sediment found in streams of this area. Wind erosion is also very active on the loose sands, especially those that are cultivated.

About half of the area is in a native cover of sand-sage and shinnery oak, and is used for grazing. The remainder is used chiefly for the raising of cotton and grain sorghums.

Due to the fact that most stream channels are blocked with sterile sand deposits, very little alluvial land is used for crops. Flood damages therefore are slight in this area.

<u>Rolling Red Plains, Rough Lands Area:</u> This area is found in the central part of Roger Mills County, Oklahoma in the form of a large "C". It occupies about 232,000 acres, and is composed predominantly of rough broken lands and thin stony soils on short steep slopes. The soils are developed from sandstone and shale, and on steep slopes have little or no remaining top soil. Infiltration rates are low, and runoff and erosion rates are high. It is estimated that the annual rate of soil loss approaches 7.5 acre-feet per square mile, which is the highest in the watershed.

Rangeland occupies about 90 percent of the area, and cropland and miscellaneous use make up the remainder. The small amount of cropland is located on the level to gently rolling bench lands along the major streams. Flood damages in this area are small, since the alluvial area is not intensively used. This area however, produces runoff and erosional debris which cause great damage in the area below.

<u>Rolling Red Plains, Red Mixed Soils Area:</u> This area covers some 1,060,000 acres in Roger Mills, Custer and Washita Counties, Oklahoma.

The topography is generally rolling to strongly rolling, and becomes steeper along the major drainageways. Some smoother slopes of heavier soils occur on drainage divides, especially south of the Washita River. Most of the level lands are found in the flood plains. The soils are red very fine sands and sandy clay loams, and are highly erodible. The parent material consists of red gypsiferous shales and sandstones and is loosely consolidated. Even when the entire soil profile is lost, erosion continues to be active on the parent rock. Sheet erosion is active over the entire area, but the chief erosion problem is the headward gully development in minor tributaries. Overfalls often are 20 to 30 feet deep.

About 68 percent of the area is devoted to the production of crops such as wheat, cotton, and grain sorghums. Grazing land occupies about 28 percent of the area, and miscellaneous uses the remaining four percent. The native cover is of the short grass transition type, and in general is only in fair condition.

Flood damages in this area are high. The flood plains are intensively used, and damaging floods occur frequently. Sediment output is great, but due to the fine texture of the sediment, it does not cause as much damage as might otherwise be expected.

6 Rolling Red Plains, Heavy Soils Area: This area is located in Kiowa County, Oklahoma, and covers about 180,000 acres. About 70 percent of the area consists of dark heavy mature soils on gently rolling topography. These soils are intensively cultivated to wheat, cotton and grain sorghums. The remaining 30 percent of the area consists of shallow soils, and is devoted to the grazing of cattle.

Infiltration rates are moderately low, but the water holding capacity of the soil is large. Surface runoff is slow due to the

gently rolling topography, and therefore erosion losses are slight.

Granitic Soils

This problem area consists of the Wichita and Arbuckle Mountains and occupies about 250,000 acres. It is found in three separate units, in Johnston, Garvin and Kiowa Counties, Oklahoma. The topography is hilly to mountainous with over half the area occurring on slopes above 10 percent. Soils are derived primarily from alternate bands of sandstone, limestone and shales, and in some areas from the exposed granite. About two-thirds of the soils are either very shallow or rough broken, and the remainder shallow to deep.

About 65 percent of the area is devoted to ranching, and 30 percent to the production of crops such as wheat and grain sorghums. The remaining five percent is in miscellaneous uses.

The ranch lands are in good condition generally, and erosion losses are slight. Even on the cultivated areas erosion is not severe.

Only a small amount of flood plain is found in the area, therefore flood damages are slight.

Reddish Prairies

This problem area covers about 1,455,000 acres in the central portion of the watershed, and is closely associated with the Cross Timbers problem area in soil conservation. The topography is typically rolling, with steeper slopes paralleling the major streams, and gentler slopes occurring on the drainage divides.

Soils have been developed from sandstone and shale and vary in texture from fine sandy loams to clays. The alluvial soils, occupying about 11 percent of the area, are highly developed and are dominantly medium textured. Shallow immature soils occupy about 26 percent of the area, and mature soils the remainder.

Present land use is as follows: Cropland 805,000 acres, grazing land 528,000 acres, blackjack-post oak savanna 1/ 45,000 acres, and miscellaneous uses 77,000 acres. This is a wheat - cotton transition area, with over half the cropland devoted to row crops. Alfalfa is of considerable importance in the flood plain.

It is estimated that about 35 percent of the area is moderately to severely eroded. Little or no abandonment of land has occurred because of very severe erosion.

Because the flood plains on the main stem and the major tributaries are intensively used, flood damages are very high in this area.

Cross Timbers

The Cross Timbers occupies about 762,000 acres, and occurs in scattered tracts throughout the lower half of the watershed. The topography is rolling to strongly rolling and is characterized by many steep sided ravines, the result of accelerated erosion. The soils are medium to coarse textured and are highly erodible. The parent rock is so loosely consolidated that it too is highly erodible.

Cropland occupies about 265,000 acres, but it is estimated that about 50 percent of it has been abandoned due to erosion, and is now idle. Cotton and grain sorghums are the chief crops. Pasture of tall grasses occupies 80,000 acres and, in general, is in poor condition. Blackjack-post oak savanna occurs on 402,000 acres, and is largely used as grazing land. Here the predominant cover consists of blackjack and post oaks, with an understory of brush or tall grasses. The blackjack oak is not used commercially. Miscellaneous land uses of 15,000 acres make up the remainder of the area.

Erosion losses are very high in the Cross Timbers. Large areas of farm land have become so badly gullied that complete abandonment has

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1/ See description, page 19.

occurred. The sediment from this area has caused great damage to the flood plains below and has aggravated the already serious flood problem.

Grand Prairie

This problem area occupies about 527,000 acres in the lower fourth of the watershed. The topography is gently rolling to rolling except near the Granitic Soils areas where it is steeper. The soils have been developed from calcareous shales and soft limestones and are usually dark in color. Immature soils occupy a large portion of the area.

About 177,000 acres are devoted to the growing of cotton, corn, small grain and grain sorghums. Grazing lands occupy 272,000 acres and blackjack-post oak savanna 68,000 acres. The remainder, 10,000 acres, is in miscellaneous land uses.

Erosion is moderate in the area, and because of the fineness of the soil particles causes little damage in the flood plains.

Forested Coastal Plains

This is a relatively small area in the extreme lower portion of the watershed. It consists of 30,000 acres of cropland, 25,000 acres of grassland, 40,500 acres of woodland, and 1,500 acres of miscellaneous land. Topography is rolling to strongly rolling, and erosion is active. The soils are sandy in texture, and were developed from loosely consolidated sands and sandy clays.

Since this area lies alongside Lake Texoma, most of its sediment output finds its way directly into the lake.

TRIBUTARY AREAS

The watershed was divided into nine tributary areas in order to facilitate hydrologic investigations, figure 6, Appendix III. These divisions were made on a basis of similarity of flood plain characteristics such as agricultural development, number and size of floods,

flood damages, and other related problems. The divisions were made on watershed boundaries or along main drainageways and therefore do not conform with the problem areas in soil conservation, which follow no watershed boundaries. However, the soils, slope, land use and erosion in the various problem areas in soil conservation were given consideration when the tributary areas were set up.

GEOLOGY AND PHYSIOGRAPHY

The watershed of the Washita River includes parts of five physiographic sub-divisions, figure 2:

(a) High Plains Border
(b) Redbeds Plains
(c) Wichita Mountain Uplift
(d) Arbuckle Mountains
(e) Gulf Coastal Plain

High Plains Border

This province is transitional between the true High Plains on the west and the Redbeds Plains on the east. It consists of rough and rolling topography, dissected by numerous eroding streams. The entire area is covered by sandy terrace deposits and dune sand of Quaternary age, which contribute substantially to the valley sediment and bed load of the Washita and its tributaries. A small, flat area of typical High Plains occurs in the extreme western edge of this section.

Redbeds Plains

This sub-division occupies most of the area drained by the Washita. The Quartermaster, Cloud Chief, Whitehorse and Clear Fork-Wichita formations are the principal geologic units. This area formerly contained a deep inland sea into which thick sections of sediment were deposited. The rocks commonly dip toward the axis of a basin which is roughly a line extending from about northeastern Stephens County, Oklahoma, to northeastern Wheeler County, Texas. The general structure

Source: Oklahoma & Texas State Geologic Maps

Figure 2

GENERALIZED GEOLOGIC MAP

WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS

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of the basin does not greatly influence the course of the river except at a point near northeastern Kiowa County, Oklahoma, where the course is deflected eastward by steeply northward dipping strata. The haystack topography of the Quartermaster formation, consisting of shales, fine sandstones and siltstones, is conducive to rapid runoff. The surface topography of the Cloud Chief formation does not greatly affect surface runoff. The Whitehorse sandstone, because of its soft and massive character, has a greater waterholding capacity, and the quality of the water is much more desirable than in the other two formations. The Dog Creek-Blaine and Chickasha-Duncan groups occupy relatively small areas and consist chiefly of reddish sandstones, siltstones and vari-colored shales. The oldest Permian formation is the Clear Fork-Wichita group, which is mostly red sandstone and sandy shales.

Wichita Mountain Uplift

This sub-division, consisting of granitic peaks, lies within the outcrop area of the Clear Fork-Wichita formation along the south margin of the watershed. The uplift has little effect on floods.

Arbuckle Mountains

The Arbuckle Mountains are a highly folded and faulted area, located mostly in Johnston and Murray Counties, Oklahoma. The oldest rocks are exposed as granitic cores surrounded by somewhat concentric layers of progressively younger rocks, principally limestone, which dip outward. They have a local relief of about 700 feet. Runoff is low as infiltration rates are relatively high. The high infiltration rate is made possible by the almost vertically tilted beds of the mountains, which often extend above the surface of the ground and act as baffles for surface runoff. The many springs at the base of the

mountains indicate that infiltration is high. One in particular, occurring at the head of Birds Mill Creek, about 12 miles south of Ada in Pontotoc County, discharges 15,000,000 gallons of water per day. Artesian wells are present in the vicinity of Sulphur as further evidence of large supplies of ground water.

In Murray County, above the gorge through the Arbuckles, it is probable that the Washita River was traversing a course somewhat similar to its present one at the time of the latest uplift, which was more rapid than the cutting action of the stream. This may have caused a partial damming of the river in the synclinal valley, creating a lake and slowing the flow to such an extent that the flood plain above was greatly widened upstream from the mountains.

Gulf Coastal Plain

The coastal plain is a comparatively small area in the lower part of the watershed in which the rocks dip at relatively low angles toward the Gulf. Before the river had bisected the Arbuckles, soft marine Cretaceous sediments were laid down in the area below the mountains. When the river bisected the mountains, it quickly entrenched itself in the sediment, cutting a deep channel through the soft sandstones and shales. The channel capacity immediately below the mountains is approximately twice that above. The gradient decreases from five feet per mile through the gorge to less than two feet per mile through the coastal plain.

Physiographic Summary

The elevation at the mouth of the Washita River is about 500 feet above mean sea level. Elevations gradually rise upstream along the valley to a maximum of about 3,000 feet at the head of the Washita River on the eastern edge of the High Plains. The Arbuckle and Wichita mountain

uplifts are the most conspicuous interruptions on the generally rolling topography. The drainage pattern is predominantly dendritic and the smaller valleys have relatively steep slopes and high gradients.

Nearly one-eighth of the drainage area has slopes steeper than 13 654 percent. Gentle slopes of 3 percent or less occupy 2,113,902 42 percent of the basin and slopes of 4 to 12 percent occupy 2,315,226 46 percent of the area. The steepest slopes are almost entirely in the two mountainous areas. One feature of the Washita Basin is the extensive, relatively wide alluvial bottomlands which cover approximately 1,006,620 ac. 20 percent of the total area.

CLIMATE

The climate of the Washita River Watershed is temperate, and falls almost entirely in the sub-humid climatic zone. The mean annual temperatures range from 58°F in the upper end of the watershed to 64°F in the lower portion. The average frost-free period varies from 197 days in the Texas portion of the watershed to 233 days near Lake Texoma.

The average annual precipitation in the Texas portion of the watershed is 23 inches, with extremes of 12.24 to 39.45 inches. In the lower reaches the average is 38 inches, with extremes of 19 to 58 inches. Rainfall distribution is highly erratic. Drouths of from three to eight weeks occur during practically every growing season. These drouths are usually accompanied by hot, dry winds, thus aggravating moisture conditions. Interspersed with such drouths are storm periods, usually violent and of short duration, which produce intense rainfall over small areas. Less frequently rainfall associated with polar air masses falls over larger areas.

LAND USE

Present land use by problem areas in soil conservation is shown in table 2. Land use figures were obtained from the Conservation Needs

Table 2 - Present Land Use by Problem Areas in Soil Conservation

Washita River Watershed

Problem Areas in Soil Conservation	Present Land Use: Cropland	Open Grazing Land	Blackjack: Post oak Savanna	Woodland	Misc.	Total
High Plains	4,528	1,081	-	-	168	5,777
Rolling Red Plains	1,069,030	837,872	-	-	29,987	1,936,889
Reddish Prairies	804,907	527,621	44,777	-	77,525	1,454,830
Cross Timbers	265,229	79,783	402,030	-	14,551	761,593
Grand Prairie	177,057	272,124	68,019	-	10,116	527,316
Granitic Soils	72,656	89,709	71,029	-	16,077	249,471
Forested Coastal Plains	29,791	25,262	-	40,693	1,488	97,234
Total	2,423,198	1,833,452	585,855	40,693	149,912	5,033,110 1/

1/ 61,930 acres occupied by Lake Texoma not included. Total area of watershed is 5,095,040.

Study conducted by the Soil Conservation Service in 1949.

Conservation Surveys have been made on nearly half of the watershed. From an analysis of these surveys, land capability classes by land uses were obtained by expansion, table 3.

Cropland, including idle land, occupies 47.6 percent of the watershed area; open grazing land 36.0 percent; blackjack-post oak savanna 11.5 percent; woodland 0.8 percent; and miscellaneous uses 2.9 percent; Lake Texoma covers 61,930 acres or 1.2 percent of the watershed area.

RATE OF SOIL LOSS

Erosion damage has been most severe in the cultivated fields in the central part of the watershed. Losses have been slight on most of the grazing land in the Arbuckle and Wichita Mountains, and relatively low

Table 3 - Land Capabilities 1/ in Acres - Washita River Watershed

497,856

Present Land Use	I	II	III	IV	V	VI	VII	VIII	Total
Cropland	271,747	488,750	953,208	211,637	23,209	25,964	448,683	-	2,423,198
Open Grazing Land	47,388	153,008	420,570	130,809	39,222	279,262	763,052	141	1,833,452
Blackjack-Post Oak Savanna	13,396	40,030	149,229	51,024	15,431	39,086	277,659	-	585,855
Woodland	13,396	1,319	10,412	4,750	-	-	24,212	-	40,693
Miscellaneous	-	-	-	-	-	-	-	149,912	149,912
Total	332,531	683,107	1,533,419	398,220	77,862	344,312	1,513,606	150,053	5,033,110
Lake Texoma	-	-	-	-	-	-	-	-	61,930
Total Area									5,095,040

1/ Land capabilities are described as follows:

CLASS I Land suitable for cultivation with few or no permanent limitations and no hazards to the maintenance of the land.

CLASS II Land suitable for cultivation with moderate permanent limitations or moderate hazards to the maintenance of the land.

CLASS III Land suitable for cultivation with severe permanent limitations or frequent hazards to the maintenance of the land.

CLASS IV Land suitable for cultivation with very severe permanent limitations or very frequent hazards. It may be cultivated only between long time or irregular periods of permanent vegetation or may be used for limited cultivation.

CLASS V Land not suitable for cultivation but suitable for permanent vegetation, grazing, or forestry with few or no permanent limitations or slight hazards.

CLASS VI Land not suitable for cultivation but suitable for permanent vegetation, grazing, or forestry with moderate permanent limitations or moderate hazards.

CLASS VII Land not suitable for cultivation, but suitable for permanent vegetation, grazing, or forestry with severe permanent limitation or severe hazards.

CLASS VIII Land whose physical conditions impose such extreme limitations or hazards that it is not suited for cultivation, grazing, or forestry use, but which may be suited for wildlife use, recreational purposes, or vegetation for watershed protection. (In this table miscellaneous land also includes roads, railroads, cities, etc.)

on the remainder of the grazing land. Wind erosion has been most severe on the sandy cultivated lands in western Roger Mills County, Oklahoma.

About 2,000,000 acres in the watershed show slight accelerated erosion. This land is mostly in the alluvial flood plain and the better range lands. An additional 2,000,000 acres are moderately eroded, and slightly over 1,000,000 acres are severely eroded.

It is estimated that the present annual rate of soil loss is 2.17 acre-feet per square mile, or an annual total of 17,275 acre-feet. This amounts to about 32,000,000 tons of soil per year, or an average of 6.27 tons per acre.

COVER CONDITIONS

As in most of the southwest a wide variety of vegetation occurs as a result of differences in topography, soils and climate. Three main vegetative sites dominate the watershed. These are: (1) mixed, sandy grassland site, (2) hard grassland site, and (3) Blackjack and Post Oak grassland site, or savanna.

Mixed Sandy Grassland Site

The better grasses for this site in the eastern half of the watershed are: big and little bluestem, Indiangrass and switchgrass. For the western part of the watershed the better grasses are sand bluestem, Indiangrass, sand lovegrass, little bluestem and switchgrass.

With continuous overuse these better grasses are gradually replaced by undesirable plants such as annual three-awn, annual ragweed, western ragweed, ironweed, broomsedge bluestem, sand dropseed and others.

Hard Grassland Site

For the eastern half of the watershed the better grasses are big and little bluestem, Indiangrass and switchgrass. The western half

contains little bluestem, sideoats grama, Indiangrass, blue grama and switchgrass.

As the better grasses are overused less palatable and less productive plants such as three-awn broomweed, western ragweed, tumblegrass, hairy grama and splitbeard bluestem appear.

Blackjack-Post Oak Site

This site, referred to as blackjack-post oak savanna throughout this report, occurs principally in the eastern one-half of the watershed. It is characterized by thin to dense stands of oak trees and brush on mixed to sandy soils. The better grasses are big and little bluestem, sand lovegrass, Indiangrass and switchgrass.

As the better grasses go out through heavy use they are replaced by less desirable species such as three-awn, ragweed, broomsedge, tumblegrass and sand dropseed. The brush also increases considerably with overuse of the better grasses.

Geologic References - Washita River Watershed

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4. Geology of Hemphill County Texas, Reed and Longnecker, University of Texas Bulletin No. 3231, 1932.

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APPENDIX II

LAND AND WATER ECONOMY

SETTLEMENT AND DEVELOPMENT

Cattle drives through the Texas portion of the Washita River Watershed developed the open grazing of the range land about 1820 and a short time thereafter permanent ranching prevailed. Following the war between the States large areas of this portion of the watershed were among the tracts granted to railroads as inducement for extension of railway services into the area. Railroads in turn divided their grants into smaller tracts and sold them to ranchers and farmers.

Dewey, Custer, Beckham, and Roger Mills Counties, at the upper end of the Oklahoma portion of the watershed, were opened to settlement in 1892. This settlement progressed in accordance with the Homestead Act and the tracts were, therefore, typically 160 acres in size. This small size of tracts caused emphasis to be placed on cash crop farming in areas unsuited to such practices. In an effort to obtain a satisfactory income, land was placed under cultivation which should have remained in grass. The breaking out of land unsuitable for cultivation plus continuous overgrazing of much of the remaining grassland accelerated erosion and runoff in this portion of the watershed.

Although the middle area of the watershed was not opened to settlement until 1901, much infiltration had occurred prior to this date and actual development began about 1892. The small size of homesteads, 80 to 160 acres, along with the natural adaptability of the area to cotton and other clean-tilled crops encouraged

cropping practices conducive to erosion and runoff.

The remainder of the watershed previously held communally by the Chickasaw Indian Tribe was opened to settlement in 1895. It was at this time that communal holding of land was invalidated and allotments to Indians were made on the basis of 160 acres for each headright and subdivided among those holding fractional headrights. In many instances, Indians were given individual allotments consisting of four or five tracts of land and these tracts were sometimes widely separated. Even before 1895 white settlers had located on the more accessible lands of the territory. Tracts upon which they settled were rented from the Chickasaw Tribe and when allotments were made settlers were allowed to keep their lands by paying a nominal sum as purchase price. Such policies, combined with subsequent divisions of many homesteads, have been responsible to a large extent for the small farm units in this part of the watershed. Physical conditions of the Arbuckle Mountain region cause it to be an exception to these small farm units. These conditions are such that the area is restricted primarily to ranching.

Cotton and general farming have prevailed throughout the extreme lower section of the watershed and cropping practices, influenced by the many small units, have accelerated erosion and increased runoff.

POPULATION

Population of the Washita River Watershed was approximately

214,000 persons in 1940. 1/ Rural population accounted for about 79 percent of the totals. In 1930 approximately 80 percent of the total population was classed as rural.

Population Density

Density of rural population in the drainage area was about 21 persons per square mile in 1940 as compared with a density of 27 for the total population. There are extreme differences in the rural densities throughout the watershed. Sections in the upper end of the basin had a rural population of fewer than 10 persons per square mile in 1940 while some sections in the lower portion of the watershed had more than 30, table 4.

Population Changes

Between 1920 and 1930 the total number of persons residing within the Washita Watershed increased by almost 18 percent. Increases were reported in nearly all sections of the watershed with the greatest increase in the upper end. During this period commercial agriculture was expanding and the upper areas of the watershed, where this type of agriculture prevailed, showed a marked increase in population. This same period was prosperous for manufacturing and most industry and they furnished employment for surplus farm population. Large surpluses of farm population migrated from rural communities under these conditions.

Between 1930 and 1940 upper areas of the watershed, bearing the adverse effects of severe droughts and reflecting the greatest

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1/ Adapted from U. S. Census, 1940.

Table 4 - Population Density by Counties and States 1/

Washita River Watershed

State and County	Area in Watershed	Total Population in Watershed Area	Density Total Population	Rural Population in Watershed Area	Density Rural Population
	Sq. Mi.	No.	Persons Per Sq. Mi.	No.	Persons Per Sq. Mi.
Oklahoma					
Beckham	41.3	649	15.7	649	15.7
Bryan	82.0	2,474	30.2	2,474	30.2
Caddo	1,003.6	33,901	33.8	28,322	28.2
Canadian	6.8	138	20.3	138	20.3
Carter	465.4	14,682	31.5	14,682	31.5
Comanche	32.5	478	14.7	478	14.7
Custer	714.5	16,609	23.2	9,873	13.8
Dewey	63.4	743	11.7	743	11.7
Garvin	771.1	29,796	38.6	24,692	32.0
Grady	829.2	35,222	42.5	18,362	22.1
Johnston	410.5	9,975	24.3	9,975	24.3
Kiowa	357.5	7,895	22.1	7,895	22.1
McClain	234.8	6,596	28.1	6,596	28.1
Marshall	192.7	7,078	36.7	4,484	23.3
Murray	422.5	13,726	32.5	8,756	20.7
Pontotoc	8.6	296	34.4	296	34.4
Roger Mills	789.1	7,429	9.4	7,429	9.4
Stephens	333.9	8,487	25.4	8,487	25.4
Washita	730.3	16,876	23.1	14,100	19.3
Totals or Average	7,490.0	213,050	28.4	168,431	22.5
Texas					
Hemphill	391.9	852	2.2	852	2.2
Roberts	18.4	12	0.7	12	0.7
Wheeler	60.7	541	8.9	541	8.9
Totals or Average	471.0	1,405	3.0	1,405	3.0
Watershed Total	7,961.0	214,455	26.9	169,836	21.3

1/ Adapted from U. S. Census, 1940. Proportion of rural population for each county in the watershed was determined on basis of area within the watershed.

progress of mechanization in agriculture for the watershed, lost large numbers of inhabitants. Substitution of machines for man and horsepower permitted fewer farmers to operate the same areas. At this same time agricultural programs promoted a more extensive use of farm land by a reduction of cotton acreages, and an increase in sown crops and of pasture. While a few scattered areas showed gains in population in 1940, existing conditions influenced a general movement of population from most sections of the watershed. Table 5 shows population changes for the years 1920, 1930 and 1940.

VALUE AND SIZE OF FARM UNITS

Values of farm units in all sections of the Washita Watershed showed a sharp decline between 1930 and 1940, table 6. This decline was largely due to the depressed conditions of agriculture under which the farmers were operating. Many farmers had been forced from agriculture while others adopted an exploitative system of farming in an effort to survive. This exploitation tended to accelerate erosion and increase runoff, thus increasing flood hazards. Following 1940 the steady increase in farm values and income has permitted the farmer to more readily meet fixed charges and to express more choice in enterprise organization. This better financial position has allowed adjustment of businesses to meet changes in prices of farm products.

During the period 1930 to 1945, there was, with few areas excepted, a general increase in the size of farm units within the watershed, table 7.

Table 5 - Population and Population Changes, 1920, 1930 and 1940 by County Areas 1/

Washita River Watershed

State and County	Total Population 1920	Total Population 1930	Total Population 1940	Percent Change 1920-1930	Percent Change 1930-1940	Rural Population 1930	Rural Population 1940	Per. Change 1930-1940
	(Number)	(Number)	(Number)			(Number)	(Number)	
Oklahoma								
Beckham	666	928	649	39.3	-30.1	928	649	-30.1
Bryan	2,936	2,183	2,474	-25.6	13.3	2,183	2,474	13.3
Caddo	27,585	41,036	33,901	48.8	-17.4	36,000	28,322	-21.3
Canadian	116	150	138	29.3	- 8.0	150	138	- 8.0
Carter	14,493	14,277	14,682	- 1.5	2.8	14,277	14,682	3.6
Comanche	461	562	478	21.9	-15.0	562	478	-15.0
Custer	12,743	20,070	16,609	57.5	-17.2	12,558	9,873	-11.4
Dewey	771	821	743	6.5	- 9.5	821	743	- 9.5
Garvin	31,220	29,988	29,796	- 4.0	- 0.6	25,753	24,962	- 3.1
Grady	28,764	40,384	35,222	40.4	-12.8	22,598	18,362	-18.8
Johnson	12,578	8,176	9,975	-35.0	22.0	8,176	9,975	22.0
Kiowa	6,975	8,528	7,895	22.3	- 7.4	8,528	7,895	- 7.4
McClain	6,719	7,691	6,596	14.5	-14.2	7,691	6,596	-14.2
Marshall	8,193	6,244	7,078	-23.8	13.4	4,041	4,484	11.0
Murray	12,992	12,304	13,726	- 5.3	11.6	8,062	8,756	8.6
Pontotoc	275	254	296	- 7.6	16.5	254	296	16.5
Roger Mills	7,361	9,801	7,429	33.1	-24.2	9,801	7,429	-24.2
Stephens	7,940	9,240	8,487	16.4	- 8.2	9,240	8,487	- 8.2
Washita	16,591	22,095	16,876	33.2	-23.6	19,159	14,100	-26.4
Subtotals	199,379	234,732	213,050	17.7	- 9.2	190,782	168,431	-11.7
Texas								
Hemphill	883	1,084	852	22.7	-21.4	1,084	852	-21.4
Roberts	11	10	12	- 9.1	20.0	10	12	20.0
Wheeler	374	716	541	91.4	-24.4	716	541	-24.4
Subtotals	1,268	1,810	1,405	42.4	-22.4	1,810	1,405	-22.4
Total	200,647	236,542	214,455	17.9	- 9.3	192,592	169,836	-11.8

1/ Based on U. S. Census, 1920, 1930 and 1940.

Table 6 - Value of Farms (Land and Buildings) and Average Value Per Acre By Counties 1/

Washita River Watershed

State and County	Value of Farms (Land and Buildings)				Average Value Per Acre			
	1930	1935	1940	1945	1930	1935	1940	1945
	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)	(Dollars)
Oklahoma								
Beckham	926,207	593,562	483,652	752,815	40.11	23.65	19.59	30.55
Bryan	1,122,390	665,188	784,023	864,626	29.86	16.63	18.88	21.19
Caddo	27,949,316	19,249,412	18,942,815	25,557,758	46.00	30.66	30.07	39.70
Canadian	245,919	177,213	191,007	258,303	57.66	41.83	45.43	58.34
Carter	4,554,261	2,822,830	4,231,040	4,518,910	27.52	13.28	22.04	18.72
Comanche	511,448	336,054	353,880	416,379	30.00	20.06	22.68	26.39
Custer	17,145,707	10,561,506	12,069,771	19,196,284	39.17	24.37	28.42	41.72
Dewey	860,097	625,473	650,517	869,826	24.47	17.50	17.54	23.25
Garvin	15,107,822	11,613,483	11,523,209	14,505,196	38.26	27.59	27.15	32.18
Grady	22,590,724	14,977,733	14,328,309	19,617,119	47.46	31.04	28.92	38.90
Johnston	4,127,500	2,483,675	3,899,694	3,022,758	20.74	12.68	16.56	14.81
Kiowa	10,666,552	6,787,634	6,734,142	9,665,724	50.99	30.90	31.31	44.96
McClain	5,763,912	4,115,825	4,404,959	4,666,943	43.52	30.39	33.01	33.35
Marshall	2,119,847	1,327,400	1,919,871	1,434,526	23.48	14.06	19.74	17.31
Murray	4,674,453	3,027,883	3,341,049	5,250,642	28.66	16.65	19.43	23.65
Pontotoc	116,390	72,316	81,934	99,706	29.85	16.34	19.31	22.19
Roger Mills	9,292,523	6,855,208	5,798,818	7,762,465	20.27	14.41	11.90	15.19
Stephens	4,973,041	3,291,168	2,947,732	4,662,333	30.23	19.55	17.46	25.30
Washita	25,328,429	16,573,857	17,018,595	23,679,830	57.28	36.33	38.35	51.35
Texas								
Hemphill	3,095,346	2,191,603	2,535,945	4,364,602	17.31	10.01	11.62	19.34
Roberts	172,268	124,904	108,952	179,694	13.63	10.46	8.68	14.59
Wheeler	983,984	631,201	568,952	658,543	31.59	18.38	15.29	23.08
Median of Average Values					30.11	18.92	19.66	24.47

1/ U. S. Census of Agriculture, 1935 and 1945.

Table 7 - Average Farm Size, 1930, 1935, 1940, 1945 By Counties

Washita River Watershed

State and County	Average Size in Acres			
	1930	1935	1940	1945
Oklahoma				
Beckham	154.1	174.0	221.4	246.9
Bryan	113.4	110.0	134.4	146.2
Caddo	129.5	143.0	180.9	187.1
Canadian	180.0	195.9	215.7	234.5
Carter	135.6	136.2	137.2	189.6
Comanche	195.1	197.6	255.1	274.2
Custer	205.2	221.0	259.8	290.0
Dewey	249.8	252.9	309.9	384.7
Garvin	115.4	116.1	143.3	150.9
Grady	128.6	132.4	168.4	188.7
Johnston	208.7	174.6	217.0	275.2
Kiowa	171.2	205.4	238.9	295.5
McClain	107.2	115.0	143.6	167.6
Marshall	146.4	139.6	169.6	202.4
Murray	162.3	158.2	181.7	254.2
Pontotoc	121.6	121.4	137.1	164.2
Roger Mills	278.3	292.1	382.6	482.7
Stephens	150.5	148.9	174.1	203.2
Washita	135.7	163.5	178.1	208.1
Texas				
Hemphill	1,048.6	1,325.5	1,518.0	1,407.8
Roberts	3,998.3	3,413.3	4,077.2	4,277.7
Wheeler	290.2	290.2	445.3	439.8
Median	158.2	168.7	198.7	240.7

1/ U. S. Census of Agriculture, 1935 and 1945.

LAND OWNERSHIP

More than 85 percent of all farm land in the Washita Watershed is owned by private individuals. 1/ Tax free lands, including restricted Indian land, account for slightly less than nine percent, and corporate interests control about five percent.

FARM TENANCY

Study of available census data reveals that the proportion of farm units operated by tenants within the Washita Watershed remained relatively the same between 1910 and 1935, table 8. Approximately 59 percent of all farms were tenant operated in 1910 while in 1935 tenants operated 62 percent of the total number of farms.

During this same period a great deal of change did occur in various sections of the watershed regarding the proportion of tenants among farm operators. In the upper sections a gradual increase in the number of tenants changed the number of farms operated by them from about one-fifth in 1910 to around one-half in 1935. Lower areas of the watershed showed a decline in the proportion of tenancy in 1935 from what it had been in 1910. Important here is the fact that all early white settlers of this area were tenants, since the land was property of the Indian tribes, and forced to remain as such until after 1895.

Although by 1935 nearly two-thirds of the farm units in the watershed were operated by tenants, the total acreage of these units was less than one-half of all farm land of the drainage area.

1/ Data supplied by Okla. Exp. Station, Dept. of Agri. Eco. Source: W.P.A. Cooperative Project No. 300. Quoted in USDA, Survey Report, Washita Watershed, March 1942, unpublished.

Table 8 - Proportion of Tenant-Operated Farms by Counties 1/

Washita River Watershed

State and County	Census of: 1930	1935	1940	1945
	(Percent)	(Percent)	(Percent)	(Percent)
Oklahoma				
Beckham	60.	56.	40.	41.
Bryan	74.	76.	42.	42.
Caddo	55.	63.	41.	41.
Canadian	55.	51.	40.	42.
Carter	63.	65.	45.	47.
Comanche	61.	62.	42.	42.
Custer	50.	50.	39.	39.
Dewey	50.	47.	38.	39.
Garvin	68.	69.	43.	43.
Grady	65.	64.	42.	43.
Johnston	74.	74.	42.	44.
Kiowa	62.	59.	40.	40.
McClain	70.	67.	41.	42.
Marshall	72.	74.	41.	41.
Murray	62.	63.	44.	44.
Pontotoc	69.	67.	42.	45.
Roger Mills	50.	51.	38.	40.
Stephens	69.	69.	44.	44.
Washita	58.	52.	39.	39.
Texas				
Hemphill	48.	42.	39.	41.
Roberts	34.	34.	41.	44.
Wheeler	58.	60.	40.	42.
Median	61.5	62.5	41.0	42.0

1/ U. S. Census of Agriculture, 1935 and 1945.

These small units necessitated a more intensive land use by the tenant in an effort to obtain the highest possible return during his tenure.

Tenancy in 1945 was considerably less for the entire watershed than in 1935. Nevertheless approximately 40 percent of the watershed farms were tenant-operated.

Not only is it important that land uses and farming practices on tenant-operated farms are often conducive to accelerated erosion and increased runoff but tenants are generally less inclined to cooperate in conservation programs than are owner-operators. The decrease in tenancy in 1940 and 1945 should be an aid in obtaining farmer cooperation in the recommended modified program.

INDUSTRIES

The principal industries in the Washita River Watershed are closely connected with agriculture. The more important of such business enterprises are grain elevators, cotton gins and compresses, cottonseed oil mills, broom factories, dairy product plants, and alfalfa mills. Some of the other major industries, not so closely connected with agriculture are crude oil production, oil refineries, stone crushers, granite quarries, nurseries, saw mills, sash and door mills, and monument works.

Transportation facilities in the watershed are adequate. In addition to paved roads connecting all the major cities in the watershed there is a secondary system of gravel and well graded earth roads. There are five railroads serving the area and an adequate network of power lines, oil and gas pipelines, and airlines.

SOIL CONSERVATION

The Department of Agriculture through its agencies and in cooperation with State and local agencies, is currently assisting

landowners and operators in the application of measures which are deemed of primary importance to the objectives of the Flood Control Act.

The Department of the Interior through the Bureau of Indian Affairs is currently assisting owners and operators of restricted Indian lands in the application of soil and moisture conservation measures. The specific practices consist of the following: brush control, contour farming, cover crops, crop rotations, stubble mulch tillage, fencing, fertilizing, pasture and meadow renovation, pest control, seeding and sodding pastures and meadows, tree planting, weed control, terracing, waterways, spring development, land leveling, and construction of farm ponds.

State interest in soil conservation has been demonstrated by passage of legislation to permit the formation of soil conservation districts. Seventeen soil conservation districts in Oklahoma and two in Texas have been organized in the watershed. These districts embrace all of the Washita River Watershed.

The State of Oklahoma is assisting local organizations of landowners in providing fire protection to 71,370 acres of blackjack-post oak savanna in Marshall and Johnston Counties.

RESERVOIRS, LEVEES AND OTHER IMPROVEMENTS

At the present there are no large reservoirs in the Washita River Watershed. However, the Washita River flows into Lake Texoma, a flood control and power reservoir impounded by a dam on the Red River immediately below the mouth of the Washita River.

There are numerous small levee systems and several channel improvements in the watershed. Perhaps the most important of these are the improvements offering flood protection to Pauls Valley and Chickasha.

IRRIGATION AND DRAINAGE

There are drainage districts operating in several parts of the watershed, chiefly in Grady, McClain, and Garvin Counties. Drainage ditches as now maintained are only partially effective and often contribute to flood damage problems.

There are no organized irrigation districts in the watershed. There is some irrigation on small scattered tracts that is done by individuals pumping from streams or wells.

APPENDIX III

HYDROLOGY

The primary objective of this appendix is to explain how the area that has been flooded, within the Washita River drainage basin, during a historical period of normal rainfall was determined; also the reductions in acres flooded that can be accomplished by the installation of a program of runoff and waterflow retardation and soil erosion prevention. Published and unpublished data collected by the U. S. Weather Bureau, the U. S. Geological Survey, the Corps of Engineers, and the U. S. Department of Agriculture Experiment Stations were supplemented by field surveys. Especially useful and valuable were the Water Supply Papers of the U. S. Geological Survey.

BASIC DATA

Precipitation Records

Standard rain gages are well distributed in and near the Washita River Watershed. Figure 3 shows the locations of the principal standard and recording rain gages which are now in operation. Also shown are the average annual rainfall over the watershed and the average monthly precipitation at three representative locations. "Rainfall" and "precipitation" are used interchangeably since snow and ice have very minor effects on runoff production in this area. Figure 4 shows the period of record for the rain gages. The records from some rain gage stations no longer in operation were used.

Stream Flow

There are six stream flow gaging stations on the Washita River main stem and two other records for stations no longer in operation. The

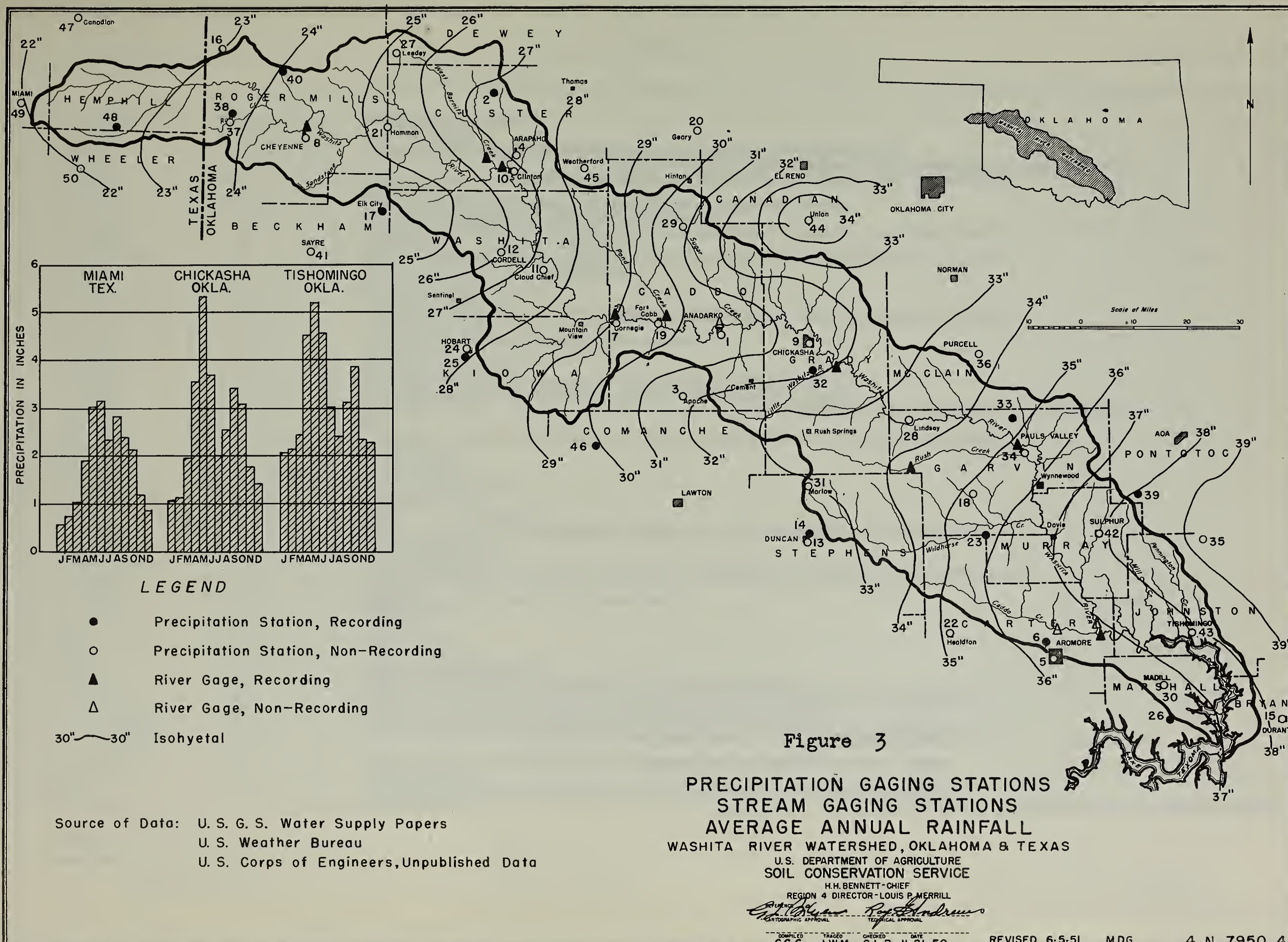
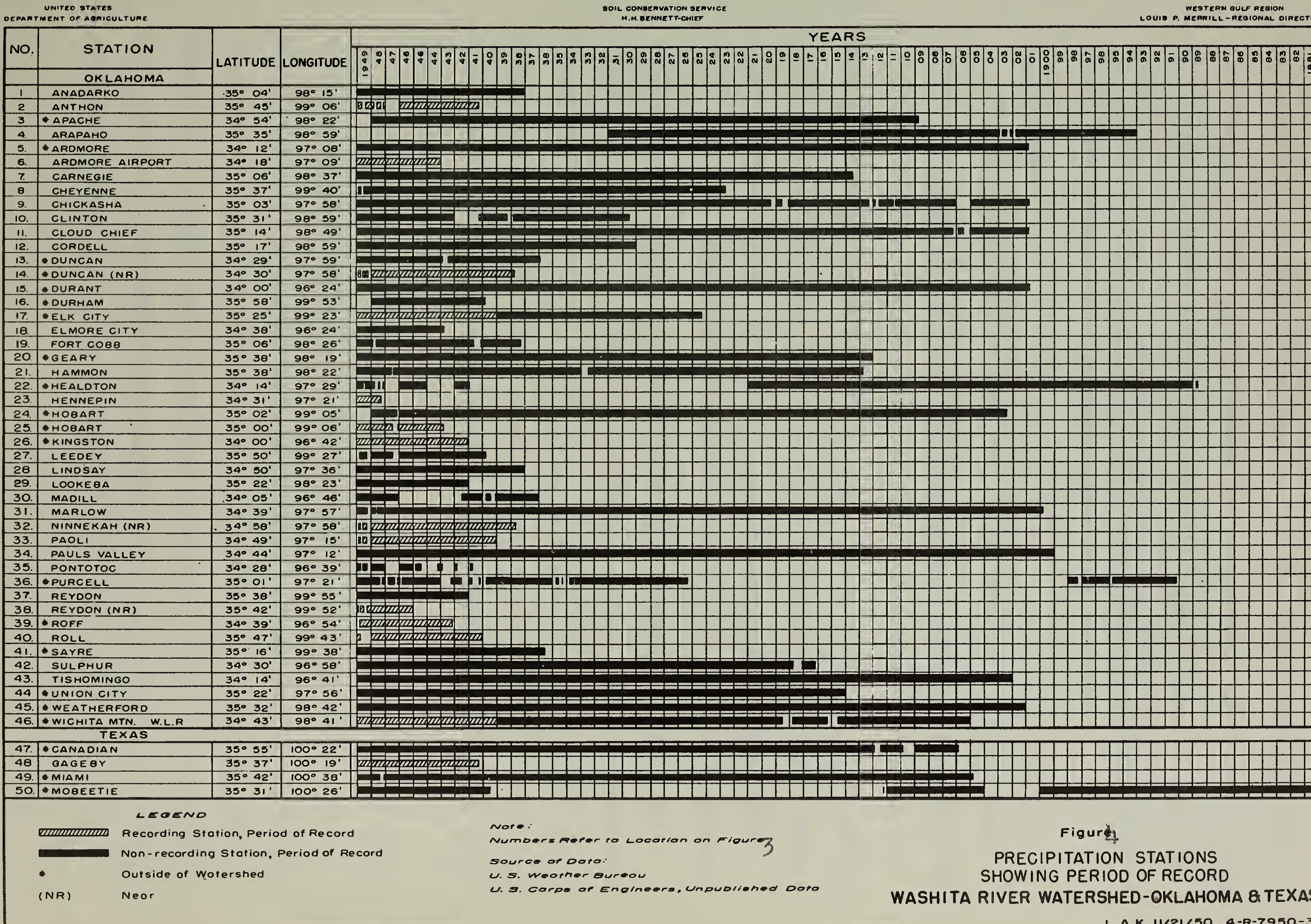


Figure 3

PRECIPITATION GAGING STATIONS
STREAM GAGING STATIONS
AVERAGE ANNUAL RAINFALL
WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

AGR-SCS-FORT WORTH, TEX JUNE, 1951


UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. BENNETT-CHIEF
WESTERN GULF REGION
LOUIS P. MERRILL-REGIONAL DIRECTOR
NO.
STATION
LATITUDE
LONGITUDE
YEARS
1949 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01 1900 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82 1881
OKLAHOMA
1. ANADARKO 35° 04' 98° 15'
2. ANTHON 35° 45' 99° 06'
3. ◆ APACHE 34° 54' 98° 22'
4. ARAPAHO 35° 35' 98° 59'
5. ◆ ARDMORE 34° 12' 97° 08'
6. ARDMORE AIRPORT 34° 18' 97° 09'
7. CARNEGIE 35° 06' 98° 37'
8. CHEYENNE 35° 37' 99° 40'
9. CHICKASHA 35° 03' 97° 58'
10. CLINTON 35° 31' 98° 59'
11. CLOUD CHIEF 35° 14' 98° 49'
12. CORDELL 35° 17' 98° 59'
13. ◆ DUNCAN 34° 29' 97° 59'
14. ◆ DUNCAN (NR) 34° 30' 97° 58'
15. ◆ DURANT 34° 00' 96° 24'
16. ◆ DURHAM 35° 58' 99° 53'
17. ◆ ELK CITY 35° 25' 99° 23'
18. ELMORE CITY 34° 38' 96° 24'
19. FORT COBB 35° 06' 98° 26'
20. ◆ GEARY 35° 38' 98° 19'
21. HAMMON 35° 38' 98° 22'
22. ◆ HEALDTON 34° 14' 97° 29'
23. HENNEPIN 34° 31' 97° 21'
24. ◆ HOBART 35° 02' 99° 05'
25. ◆ HOBART 35° 00' 99° 06'
26. ◆ KINGSTON 34° 00' 96° 42'
27. LEEDEY 35° 50' 99° 27'
28. LINDSAY 34° 50' 97° 36'
29. LOOKEBA 35° 22' 98° 23'
30. MADILL 34° 05' 96° 46'
31. MARLOW 34° 39' 97° 57'
32. NINNEKAH (NR) 34° 58' 97° 58'
33. PAOLI 34° 49' 97° 15'
34. PAULS VALLEY 34° 44' 97° 12'
35. PONTOTOC 34° 28' 96° 39'
36. ◆ PURCELL 35° 01' 97° 21'
37. REYDON 35° 38' 99° 55'
38. REYDON (NR) 35° 42' 99° 52'
39. ◆ ROFF 34° 39' 96° 54'
40. ROLL 35° 47' 99° 43'
41. ◆ SAYRE 35° 16' 99° 38'
42. SULPHUR 34° 30' 96° 58'
43. TISHOMINGO 34° 14' 96° 41'
44. ◆ UNION CITY 35° 22' 97° 56'
45. ◆ WEATHERFORD 35° 32' 98° 42'
46. ◆ WICHITA MTN. W.L.R 34° 43' 98° 41'
TEXAS
47. ◆ CANADIAN 35° 55' 100° 22'
48. GAGEBY 35° 37' 100° 19'
49. ◆ MIAMI 35° 42' 100° 38'
50. ◆ MOBEETIE 35° 31' 100° 26'
LEGEND
Recording Station, Period of Record
Non-recording Station, Period of Record
◆ Outside of Watershed
(NR) Near
Note:
Numbers Refer to Location on Figure 3
Source of Data:
U. S. Weather Bureau
U. S. Corps of Engineers, Unpublished Data
Figure 4
PRECIPITATION STATIONS
SHOWING PERIOD OF RECORD
WASHITA RIVER WATERSHED-OKLAHOMA & TEXAS
L.A.K. 11/21/50 4-R-7950-3

longest period of record (20 years) is for the gage at Durwood. There are four stream flow gaging stations on tributaries. The longest period of record is from the Ardmore gage on Caddo Creek. Figure 3 shows the location of the gages and Figure 5 shows the period of record. Table 9 gives some pertinent data from the stream gage records.

Climatology

Floods on the Washita River and its tributaries are produced by frontal, or general storms and by thunderstorms covering localized areas.

Thunderstorms are the result of local convectional action causing precipitation at excessively high rates. The area covered by a thunderstorm generally does not exceed 400 square miles. The duration usually ranges between two and six hours. Such thunderstorms occur several times each year on scattered parts of the watershed and the damages they produce are proportional to their duration and the areas which they cover. An intensity of nearly four inches per hour during a 45-minute period has been recorded, as has an intensity of over five inches per hour for a 30-minute period. Severe floods of short duration resulting from thunderstorms are quite common on the tributaries and on the upper part of the main stem.

Frontal storms are the result of dense cold polar air masses encountering warm moist air masses coming in from the Gulf of Mexico. The cooling of the moist warm air, particularly when a front remains practically stationary, results in considerable precipitation. Occasionally, disturbances along the front concentrate precipitation and, if the supply of moisture is sufficient, these pockets resemble thunderstorms within the general storm area. As an example, a storm in April 1934 which

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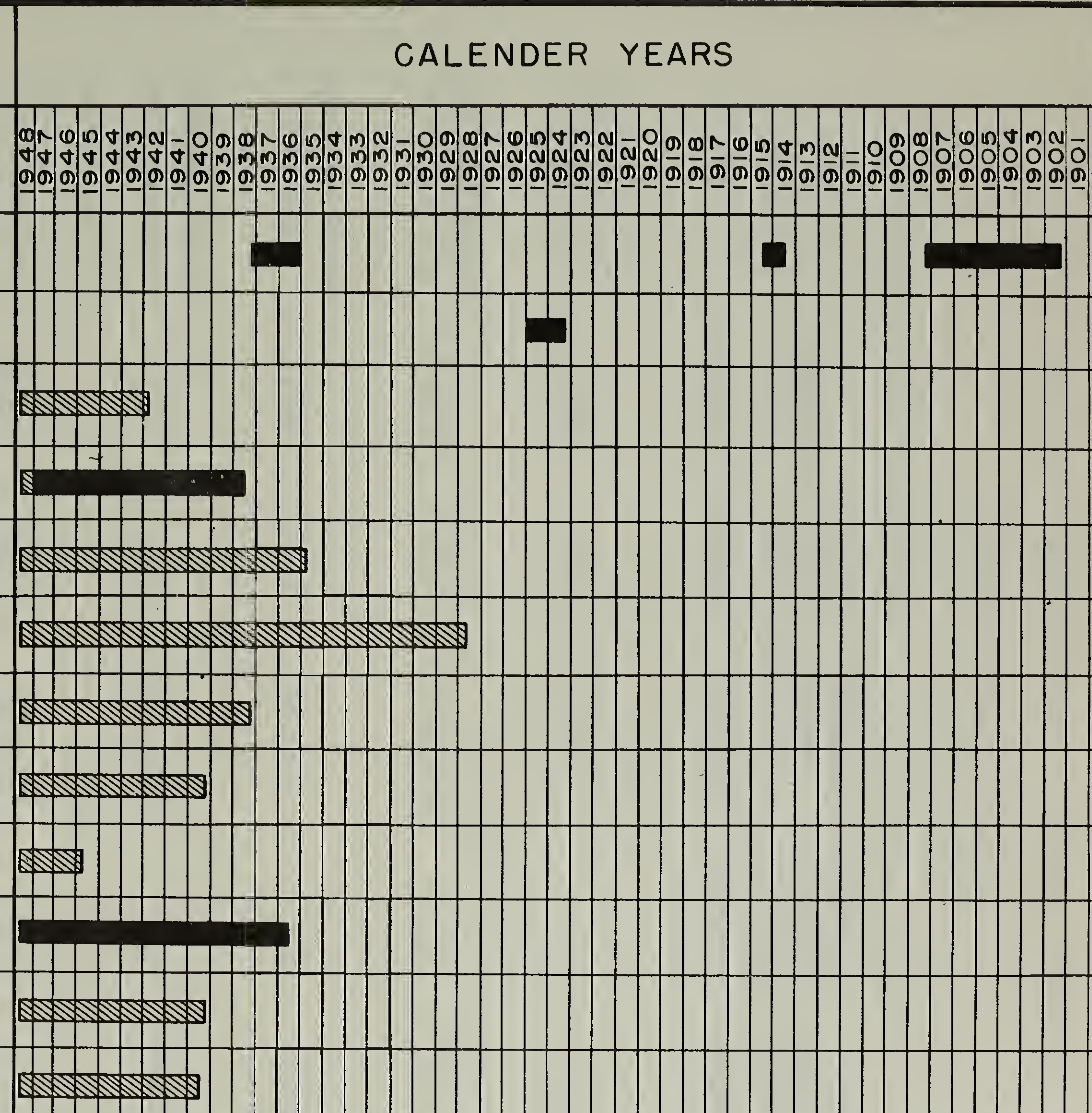
WASHITA RIVER BASIN

STREAM	STATION	DRAINAGE AREA SQ. MILES
Washita River	At Anadarko	3903
Washita River	Near Berwyn	6645
Washita River	At Carnegie	3148
Washita River	Near Cheyenne	798
Washita River	Near Clinton	1995
Washita River	Near Durwood	7210
Washita River	Near Pauls Valley	5355
Washita River	Near Tabler	4722
Barnitz Creek	Near Arapaho	247
Caddo Creek	Near Ardmore	280
Pond (or Cobb) Cr.	Near Ft. Cobb	320
Rush Creek	At Purdy	139



LEGEND

Recording

Non-recording

Source of Data: U.S. Geological Survey, Sept. 30, 1948

Figure 5

STREAM GAGING STATIONS
SHOWING YEARS OF RECORD
WASHITA RIVER WATERSHED-OKLAHOMA & TEXAS

L.A.K. 11/20/50 4-R-7950·2

AGR-SCS-FORT WORTH, TEX. JUNE, 1951

Table 9 - Water Yields by Subwatersheds 1/

Washita River Watershed

Location	Drainage Area	Period of Record	Maximum Gaged Discharge	Average Daily Discharge	Average Annual Yield	Average Annual Yield
	(Sq.Mi.)	(Years)	(C.F.S.)	(C.F.S.)	(Ac.Ft.)	(Inches)
Washita River near Cheyenne	798	9.4	40,000	43	31,252	0.73
Washita River near Clinton	1,995	13.0	26,900	163	117,659	1.11
Washita River at Carnegie	3,148	10.9	12,000	326	236,236	1.41
Washita River near Tabler	4,722	8.5	38,000	712	515,812	2.05
Washita River near Pauls Valley	5,355	10.5	22,000	941	681,152	2.39
Washita River near Durwood	7,210	20.2	91,300	1,672	1,210,334	3.15
Barnitz Creek near Arapaho	247	3.0	2,410	16	11,320	0.86
Caddo Creek near Ardmore	280	11.8	22,300	167	120,956	8.10
Pond Creek near Ft. Cobb	320	8.6	16,000	59	42,512	2.49
Rush Creek at Purdy	139	8.4	15,300	75	54,010	7.29

1/ Based on U. S. Geological Water Supply Papers through September 1948

covered two-thirds of a 1,400 square mile drainage area produced a peak flow on the main stream near Hammon, Oklahoma which was 50 percent greater than any peak flow recorded at the Durwood gage, where the drainage area is over 7,200 square miles. In this storm a precipitation of nearly 14 inches was recorded officially with unofficial readings of 20 inches being reported. The 14-inch plus rainfall covered an area of 250 square miles. The total area within the Washita River Watershed on which rainfall was recorded was 900 square miles.

The peak flow of floods on the main streams is reduced by valley and channel storage unless considerable amounts of runoff are constantly added by tributaries as the flood progresses downstream. When additional runoff is not available, the flood flows are often reduced by these factors to channel capacity or less in the lower reaches of the river. An example of this reduction in peak discharge due to valley storage is seen in the Hammond flood of 1934. On April third and fourth of this year a local storm with its axis orientated northeast-southwest through Cheyenne, produced peak discharges of 104,000 c.f.s. at Cheyenne, 88,000 c.f.s. at Clinton, and only 9,000 at Anadarko. No flooding was reported below Anadarko.

Infiltration Data

A large amount of data on infiltration rates are available from experiment stations and from numerous infiltration runs made in the field on many soil-cover complexes. Although all these data are from small plots it is possible to relate them to actual gaged records of runoff and

establish a ratio between experimental results and actual watershed conditions for any combination of soil and cover complexes. Even though it is possible to greatly reduce runoff by establishing a dense thick cover of grass on a plot of ground, the probable cover that will be established on a large area will vary from poor to excellent depending upon soil type, season, erosion, grazing management, moisture, and other variables. Average conditions likely to prevail were considered in estimating runoff reductions due to land treatment. There are sizeable areas, such as roads and urban areas, on which no reductions in runoff can be expected.

Soil-Cover Complex Classification

The areal extent of soil-cover complexes for present conditions was computed for sample tributaries by expansion from field survey data. This information on soil, slope, erosion, and land use was collected by the Conservation Surveys Division and processed by the Records and Reports Division of the Soil Conservation Service.

The areal extent of soil-cover complexes with a complete land treatment program was also computed from data derived from the conservation needs survey.

FLOODING AND FLOOD REDUCTIONS

Selection of Sample Tributaries

The watershed was divided into nine tributary areas. These areas are essentially homogeneous with respect to climate, topography, land use and soils. Subwatersheds were selected as samples to be used in expanding data to the tributary areas. Samples were selected which would represent average conditions to be found in the tributary areas,

and were sufficiently large in size to produce rating conditions which could be expanded to other subwatersheds within the tributary areas. Figure 6 shows the tributary areas and sample subwatersheds.

Field Surveys

An engineering field party was used in making field surveys. Valley cross-sections were surveyed on the sample subwatersheds and across the valley of the Washita River. Surveys were also made of waterflow retardation structure sites on the subwatershed samples.

Locations of the cross-sections and possible waterflow retardation structure sites were selected from a steroscopic examination of aerial photographs of the flood plain. Cross-sections were located at wide and narrow places in the stream valley to give an accurate flood plain acreage. Other factors considered in the location of cross-sections are land use pattern, channel cross-section, confluence of streams and topography. Field reconnaissance was made to determine the final selection of the location of cross-sections and waterflow retardation structure sites.

Computation of Basic Hydraulic Data

A downstream cross-section is selected to which data from other cross-sections are referenced. The discharge at the highwater stage of a selected storm was computed at the reference cross-section by the Manning Formula. The discharge at the other cross-sections for the selected storm was computed by the theory of concordant flow: $Q = Q_r \left(\frac{A}{A_r}\right)^x$ in which,

Q = Unknown discharge

Q_r = Discharge at reference cross-section

A = Drainage area above point of unknown discharge

A_r = Drainage area at reference cross-section

x = Exponent

Figure 6

TRIBUTARY AREAS
SHOWING SAMPLE WATERSHEDS
WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H.H. BENNETT - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL

CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

COMPILED J.O.P. TRACED D.S. CHECKED G.L.B. DATE 11-21-50

4-N-7950-1

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Stages for cross-sections other than the reference section were computed for the discharge determined by the theory of concordant flow, and checked against highwater marks which were observed by the field survey party. Necessary adjustments in the coefficient of roughness and slope of the hydraulic gradient were made to resolve differences between the results computed from field survey data and those computed by the theory of concordant flow. Figure 7 shows the relationship of the peak discharge at the reference section to peak discharge at the other cross-section. Rating curves for each cross-section were then computed as shown by table 10.

The boundary of the selected flood was delineated on aerial photographs and the area inundated in each reach of the sample subwatershed valley was planimetered and tabulated. The area inundated in each reach for the selected storm was also computed by multiplying the average of the widths of the water surface at each end of the reach by the valley length of the reach. The ratio of the computed area to the planimetered area was used as a topographic correction factor for adjusting the computed areas.

The stage-area inundation curves for various depth increments were computed for each reach and the results related to stage at the reference cross-section. The reference cross-section is used as a means of eliminating the necessity of routing each individual storm through each reach of the valley by correlating the resultant acres inundated by depth increments in each reach to stage at the reference cross-section. Stages at the reference section were correlated with runoff, in watershed inches, and the curves in Figure 8 developed.

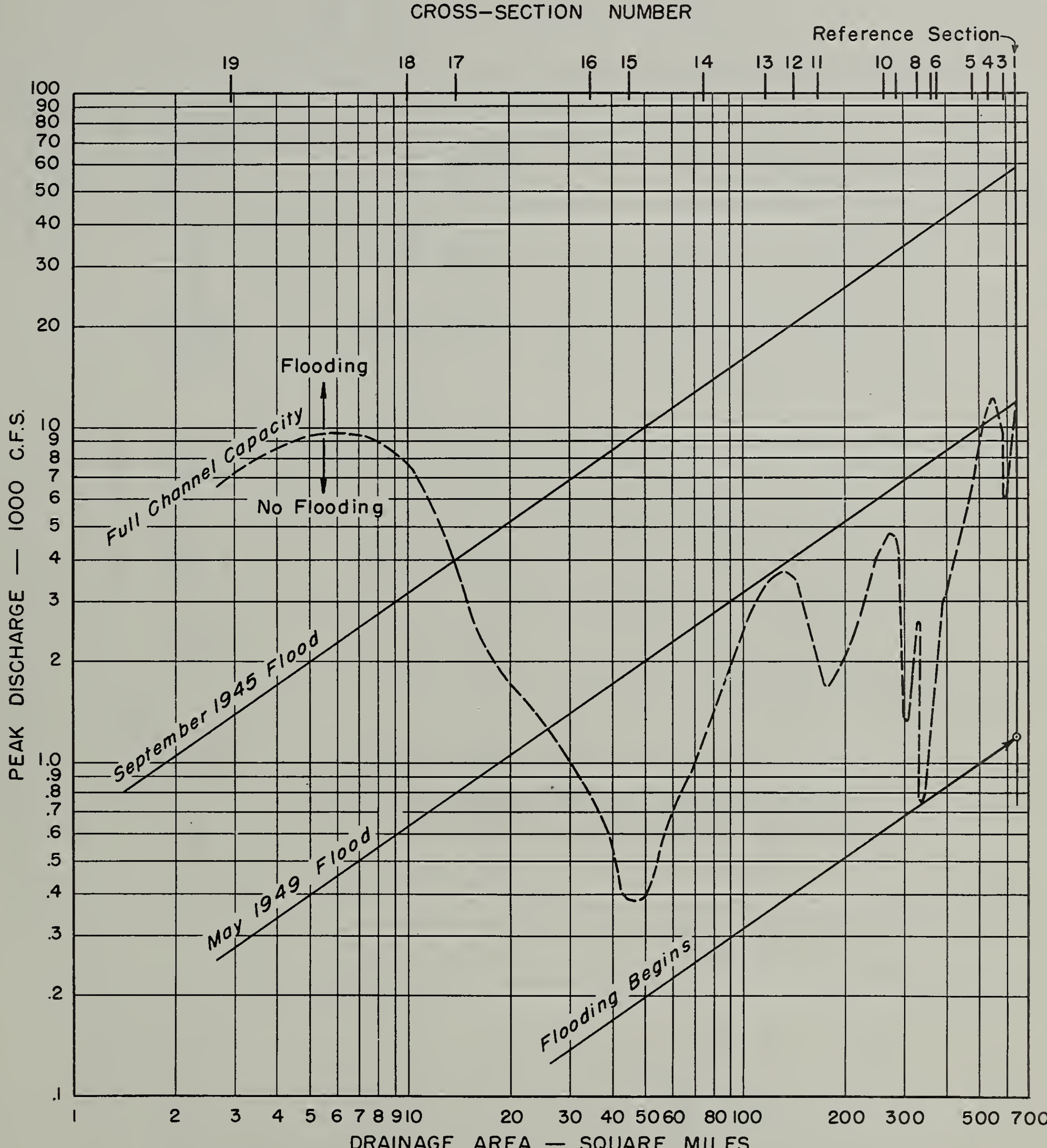

Figure 7

CONCORDANT FLOW, WILDHORSE CREEK
WASHITA RIVER WATERSHED
OKLAHOMA AND TEXAS

7-19-51 M. D. G. 4-R-7950-20

ARG-SCS-FT. WORTH TEX. 11-51

TABLE 2 STREAM DISCHARGE COMPUTATIONS

UNITED STATES
DEPARTMENT OF AGRICULTURE

WESTERN GULF REGION
LOUIS P. MERRILL-REGIONAL DIRECTOR

SOIL CONSERVATION SERVICE
H. H. BENNETT-CHIEF

RATING CURVE COMPUTATIONS WORK SHEET

Watershed Washita
Sub-Watershed Wildhorse
Section No. 7

	n= .050 @ 883.7 .055 @ 885.6 s= .00068 $s^{1/2}$=.0261 CHANNEL SECTION						s= .00089 $s^{1/2}$=.0298 OVERFLOW SECTION							TOTAL	REMARKS
Elevation of Water Surface Feet	Area of Section Sq. Ft.	Width of Water Surface Feet	Wetted Perimeter Feet	Hydraulic Radius a/p		$\frac{1.486\, ar^{2/3}s^{1/2}}{n}$	Area of Section Sq. Ft.	Width of Water Surface Feet	Wetted Perimeter Feet	Hydraulic Radius a/p		Coefficient of Roughness	$\frac{1.486\, ar^{2/3}s^{1/2}}{n}$	Overflow and Channel Section Combined	
M. S. L.	a	L	p	r	$r^{2/3}$	Q	a	L	p	r	$r^{2/3}$	n	Q	Q	
877.0						0							0	0	Bottom of channel
883.7	160	35	39.4	4.07	2.55	311+							0	360	Flooding begins
885.6	245	45	50.2	4.88	2.87	595+	1170	920	920	1.27	1.17	.065	932	1685	Highest Bank
887.9						753	6240	3160	3160	1.97	1.57	.060	7230	7983	May 1949 highwater
890.0						753	10180	3570	3570	2.85	2.01	.065	13934	14687	
893.0						753	21290	3800	3800	5.60	3.15	.065	45670	46423	
		Secondary Channel													
883.7	25	10	13	1.92	1.54	49									
885.6	65	20	23.8	2.73	1.96	158									

ARG.-SCS-FT. WORTH TEX. 11-51

C. M. D. 11-30-49 4-N-7539

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
H. H. BENNETT-CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL-REGIONAL DIRECTOR

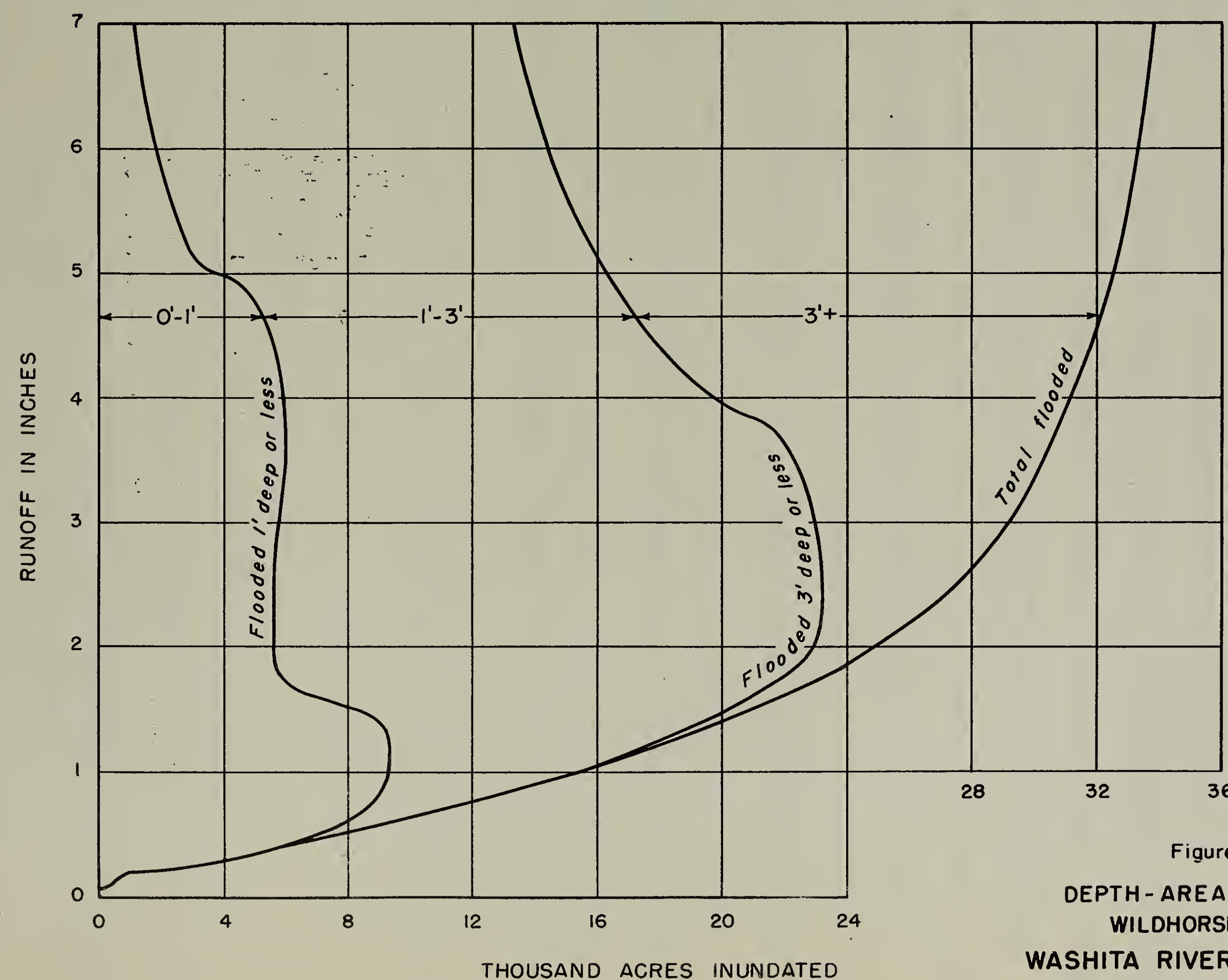

Figure 8

DEPTH-AREA INUNDATED
WILDHORSE CREEK
WASHITA RIVER WATERSHED
OKLAHOMA AND TEXAS

7·19·51 M.D.G. 4·R·7950-17

Design Criteria

Floodwater retarding structures with drainage areas up to six square miles were designed generally to contain the 25-year frequency runoff. Floodwater retarding structures for drainage areas between six square miles and 11 square miles were designed to contain a minimum of the 25-year frequency runoff to a maximum of the 100-year frequency runoff, respectively. Where possible, structures having drainage areas of 11 square miles and larger were designed to contain the 100-year frequency runoff. The structures will be rolled earth fill with uncontrolled drawdown tubes with a maximum release rate of four c.s.m., figure 9. Emergency spillways will be provided on all structures. Concrete emergency spillways will be provided on structures with drainage areas exceeding 11 square miles and which have insufficient detention capacity to contain the 100-year frequency flood. Concrete spillways will also be considered in other cases where conditions indicate their necessity or desirability. Reserve capacity will be provided in each structure to contain the expected sedimentation during a 50-year period. The rate of sediment contribution was considered to decrease uniformly to a stable value by the end of the 15-year installation period.

Rainfall-Runoff Relationship Computations

Continuous hydrographs were plotted from stream flow records of all gaged streams in the Washita River Watershed and from nearby streams with characteristics similar to those within the Washita River Watershed. The peak discharge and volume of runoff were computed for each well-defined flood crest. From these data a runoff-peak discharge curve was developed for each gaged watershed.

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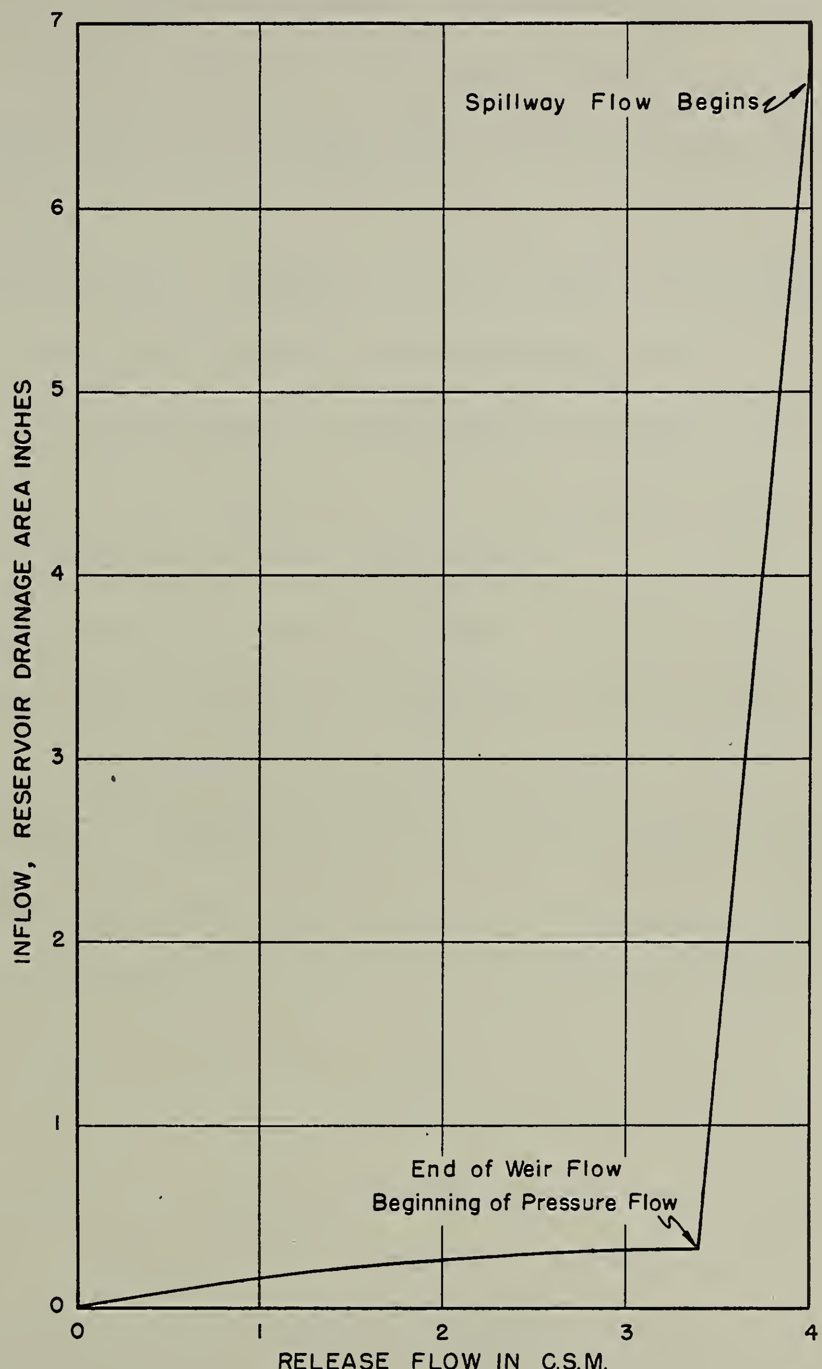

Figure 9

RELEASE FLOWS FROM
UNCONTROLLED DRAWDOWN TUBES
WILDHORSE CREEK RETARDING STRUCTURES
WASHITA RIVER WATERSHED
OKLAHOMA AND TEXAS

7-19-51 M.D.G. 4-R-7950-19

AGR-SCS-FORT WORTH, TEX. JULY, 1951

Runoff-peak discharge curves for sample subwatersheds were developed from the data from gaged watersheds which most nearly resembled them in topography, climate, soils, land use, and hydraulics of the stream channel. Figure 10 is the runoff-peak discharge curve developed for Wildhorse Creek.

The rainfall which caused the flood crests on the gaged watersheds was determined by weighting the precipitation recorded by all rain gages within or near the watershed by the Thiessen polygon method. The rainfall thus computed was plotted against the volume of runoff it produced and a rainfall-runoff curve was developed.

In order to develop a rainfall-runoff curve for the ungaged sample subwatersheds it was necessary to know the depth of runoff from each of the soil-cover complexes in the gaged watershed.

To make these computations it was assumed that the relationship of the runoff from each soil-cover complex, for any given depth of rainfall, to one of the soil-cover complexes as developed from experimental data would be the same as that relationship on the gaged watershed. A series of runoff factors was computed from experimental data expressing the runoff from each of the soil-cover complexes in relationship to the runoff from deep or shallow, fine textured soil, cultivated without land treatment measures, which has been assigned a value of unity.

A work sheet, table 11, was set up to facilitate the computation of the runoff, for rainfall increments up to 10 inches depth, for each soil-cover complex in the gaged watershed.

It is assumed that the depth of runoff, in inches from each soil-cover complex as determined from the gaged area would be the same on

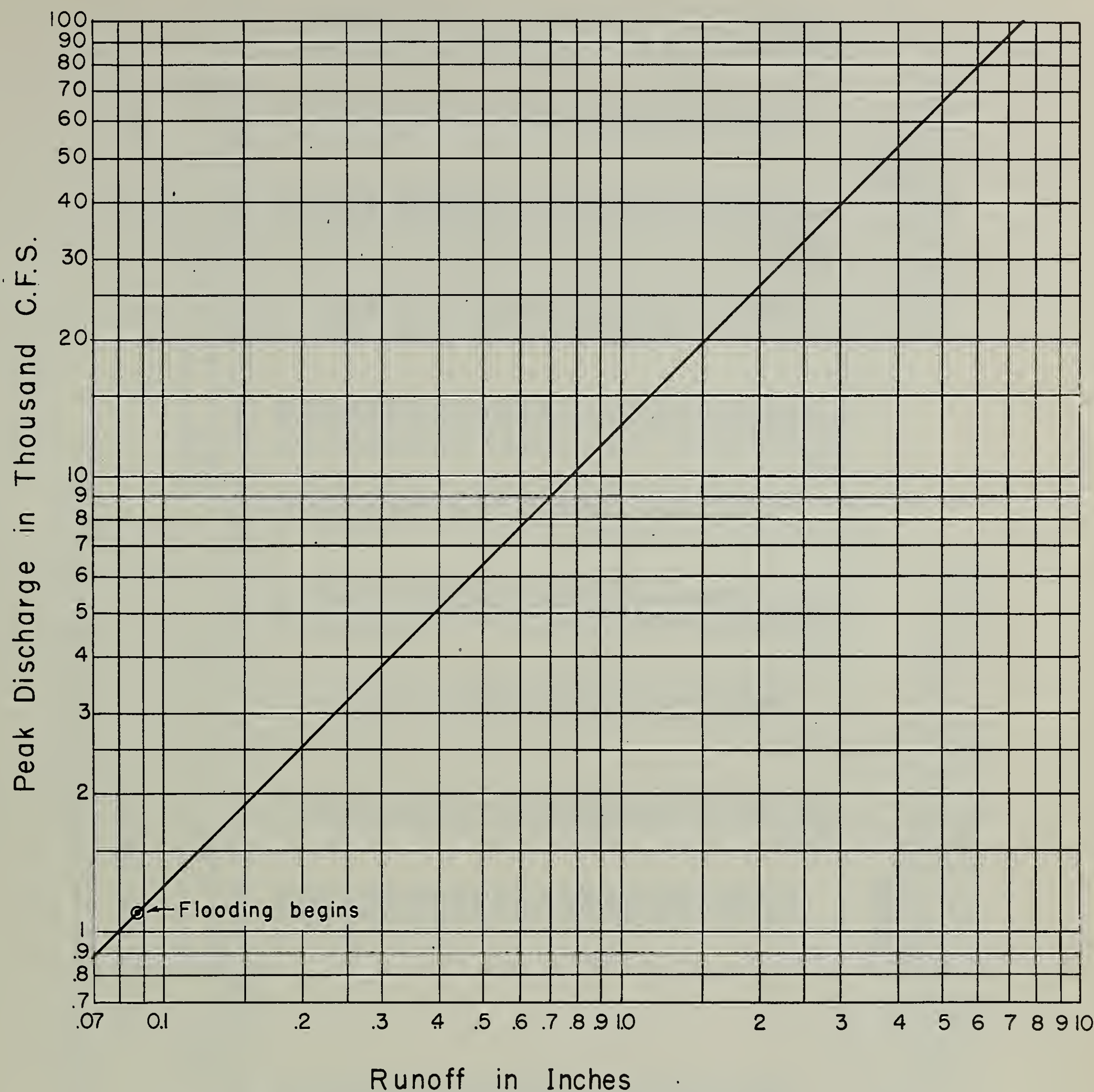

Figure 10
RUNOFF - PEAK DISCHARGE RELATIONSHIP
Cross Section No. 1
WILDHORSE CREEK
WASHITA RIVER WATERSHED - OKLAHOMA & TEXAS

A.J.H. 11-30-50 4-R-7950-10

TABLE 11 - SOIL-COVER COMPLEX DATA SHEET FOR COMPUTING RAINFALL-RUNOFF RELATIONSHIP

Present Condition

Washita River Watershed

Gaged Watershed

Soil-Cover Complex	Acres	P = 1" Factor	P = 1" Runoff	P = 2" Factor	P = 2" Runoff	P = 4" Factor	P = 4" Runoff	P = 6" Factor	P = 6" Runoff	P = 8" Factor	P = 8" Runoff	P = 10" Factor	P = 10" Runoff
Cultivated Untreated - D&S - FT	-	1.000		1.000	.708	1.000	1.993	1.000	3.392	1.000	4.832	1.000	6.332
Cultivated Untreated - D&S - MT	21,243	.750		.814	.576	.871	1.736	.902	3.060	.920	4.445	.932	5.901
Cultivated Untreated - D&S - CT	6,096	.571		.682	.483	.777	1.548	.828	2.809	.860	4.155	.881	5.578
Cultivated Untreated - VS - FT	-	1.000		1.000	.708	1.000	1.993	1.000	3.392	1.003	4.846	1.020	6.459
Cultivated Untreated - VS - MT	-	.750		.814	.576	.880	1.754	.951	3.226	.984	4.754	1.005	6.364
Cultivated Untreated - VS - CT	-	.571		.716	.507	.910	1.817	.977	3.315	1.003	4.850	1.020	6.459
Cultivated Treated - D&S - FT	-	.455		.572	.405	.678	1.351	.736	2.497	.779	3.964	.810	5.129
Cultivated Treated - D&S - MT	12,834	.167		.358	.253	.499	.994	.573	1.944	.630	3.044	.672	4.255
Cultivated Treated - D&S - CT	1,329	.047		.214	.151	.397	.791	.484	1.642	.549	2.653	.605	3.831
Pasture - Excellent - D&S	3,630	.000		.014	.010	.103	.205	.269	.912	.365	1.764	.441	2.792
Pasture - Good - D&S	13,060	.000		.074	.052	.255	.508	.372	1.262	.452	2.184	.512	3.242
Pasture - Fair - D&S	6,242	.274		.447	.316	.587	1.170	.659	2.235	.710	3.431	.745	4.717
Pasture - Poor - D&S	3,025	.667		.748	.529	.828	1.650	.866	2.938	.890	4.300	.908	5.749
Pasture - Fair - VS	-	.274		.447	.316	.765	1.525	.877	2.975	.931	4.498	.963	6.098
Pasture - Poor - VS	-	.667		.748	.529	.842	1.678	.926	3.141	.967	4.672	.991	6.275
Pasture - Fair - RB	900	.274		.615	.435	.910	1.814	.977	3.314	1.003	4.846	1.020	6.459
Pasture - Poor - RB	1,528	.667		.845	.598	.988	1.969	1.025	3.477	1.039	5.020	1.048	6.636
Woods - Good - D&S	1,938	.000		.014	.010	.103	.205	.269	.912	.365	1.764	.441	2.792
Woods - Fair - D&S	9,737	.019		.140	.099	.323	.644	.429	1.455	.501	2.421	.560	3.546
Woods - Poor - D&S	4,059	.274		.473	.335	.625	1.246	.695	2.358	.740	3.575	.774	4.901
Woods - Good - VS&RB	-	.000		.014	.010	.530	1.056	.732	2.483	.825	3.986	.873	5.559
Woods - Fair - VS&RB	800	.019		.150	.106	.682	1.359	.830	2.815	.895	4.324	.934	5.914
Woods - Poor - VS&RB	859	.274		.473	.335	.765	1.525	.877	2.975	.931	4.498	.963	6.098
Miscellaneous-Roads, Urban, etc.	1,680	1.092		1.149	.813	1.127	2.246	1.112	3.772	1.102	5.325	1.099	6.959
Total Acres and Acre-inches	88,960	-		-	28,303	-	102,333	-	196,835	-	301,500	-	415,811
Total Inches Runoff	-	-	0.00	-	0.32	-	1.15	-	2.21	-	3.39	-	4.67

D - Deep
S - Shallow
VS - Very shallow
RB - Rough broken
FT - Fine textured
MT - Medium textured
CT - Coarse textured
P - Precipitation

Pasture

Excellent - 100% cover perennial species
Good - 75% cover perennial species - good litter
Fair - 50% to 75% cover perennial species - fair litter
Poor - Less than 50% cover perennial species - no litter

Woods

Good - Neither burned or grazed
Fair - Burned or grazed
Poor - Burned and grazed

other areas, taking into consideration amount of rainfall and season of the year.

A work sheet, table 12, was set up to facilitate computing the data necessary to develop a rainfall-runoff curve for the sample subwatersheds from the data available from gaged watersheds. Figure 11 shows the rainfall-runoff curve developed for the Wildhorse Creek sample subwatershed.

Flooding on the Sample Subwatersheds

Present Conditions: The least amount of rainfall that would cause flooding at any section was determined from figures 7, 10, 11, and the rating curve for the reference section.

A period of normal precipitation was selected from a study of the U. S. Weather Bureau records of precipitation in the Washita River Watershed. The rainfall recorded at gages in and near the sample subwatersheds was tabulated on a work sheet and weighted by Thiessen polygons. All storms which produced sufficient weighted rainfall to cause flooding were marked on the work sheet. The date and weighted precipitation of the damaging storms, as explained on page 84 of Appendix IV, were tabulated into a storm series.

The area inundated, by depth increments, by each flood in the series was computed by referring to figures 11 and 8, respectively.

Table 13 shows the storms classified by magnitude and frequency.

With Land Treatment Measures: A work sheet similar to table 12 (see table 14) was completed for the sample subwatershed using the areal extent of the soil-cover complexes with a complete land treatment program applied on the watershed. The runoff for incremental values of

TABLE 12 - SOIL-COVER COMPLEX DATA SHEET FOR COMPUTING RAINFALL-RUNOFF RELATIONSHIP

Present Condition — Washita River Watershed — Wildhorse Watershed

Soil-Cover Complex	Acres	P = 1" Runoff (inches)	P = 2" Runoff (inches)	P = 4" Runoff (inches)	P = 6" Runoff (inches)	P = 8" Runoff (inches)	P = 10" Runoff (inches)
Cultivated Untreated - D&S - FT	19,732		.708	1.993	3.392	4.832	6.332
Cultivated Untreated - D&S - MT	132,737		.576	1.736	3.060	4.445	5.901
Cultivated Untreated - D&S - CT	3,257		.483	1.548	2.809	4.155	5.578
Cultivated Untreated - VS - FT	1,631		.708	1.993	3.392	4.846	6.459
Cultivated Untreated - VS - MT	936		.576	1.754	3.226	4.754	6.364
Cultivated Untreated - VS - CT	406		.507	1.817	3.315	4.850	6.459
Cultivated Treated - D&S - FT	2,192		.405	1.351	2.497	3.964	5.129
Cultivated Treated - D&S - MT	14,749		.253	.994	1.944	3.044	4.255
Cultivated Treated - D&S - CT	362		.151	.791	1.642	3.653	3.831
Pasture - Excellent - D&S	790		.010	.205	.912	1.764	2.792
Pasture - Good - D&S	16,586		.052	.508	1.262	2.184	3.242
Pasture - Fair - D&S	38,980		.316	1.170	2.235	3.431	4.717
Pasture - Poor - D&S	17,796		.529	1.650	2.938	4.300	5.749
Pasture - Fair - VS	6,047		.316	1.525	2.975	4.498	6.098
Pasture - Poor - VS	3,529		.529	1.678	3.141	4.672	6.275
Pasture - Fair - RB	415		.435	1.814	3.314	4.846	6.459
Pasture - Poor - RB	9,946		.598	1.969	3.477	5.020	6.636
Woods - Good - D&S	13,483		.010	.205	.912	1.764	2.792
Woods - Fair - D&S	75,424		.099	.644	1.455	2.421	3.546
Woods - Poor - D&S	5,316		.335	1.246	2.358	3.575	4.901
Woods - Good - VS&RB	3		.010	1.056	2.483	3.986	5.559
Woods - Fair - VS&RB	2,214		.106	1.359	2.815	4.324	5.914
Woods - Poor - VS&RB	18,166		.335	1.525	2.975	4.498	6.098
Miscellaneous-Roads, Urban, etc.	24,608		.813	2.246	3.772	5.325	6.959
Total Acres and Acre-inches	409,305		166,792	561,323	1,040,658	1,553,964	2,117,034
Total Inches Runoff	-	0.000	.408	1.371	2.543	3.797	5.172

D - Deep
S - Shallow
VS - Very Shallow
RB - Rough Broken
FT - Fine textured
MT - Medium textured
CT - Coarse textured
P - Precipitation

Pasture

Excellent - 100% cover perennial species
Good - 75% cover perennial species - good litter
Fair - 50% to 75% cover perennial species - fair litter
Poor - Less than 50% cover perennial species - no litter

Woods

Good - Neither burned or grazed
Fair - Burned or grazed
Poor - Burned & grazed

UNITED STATES
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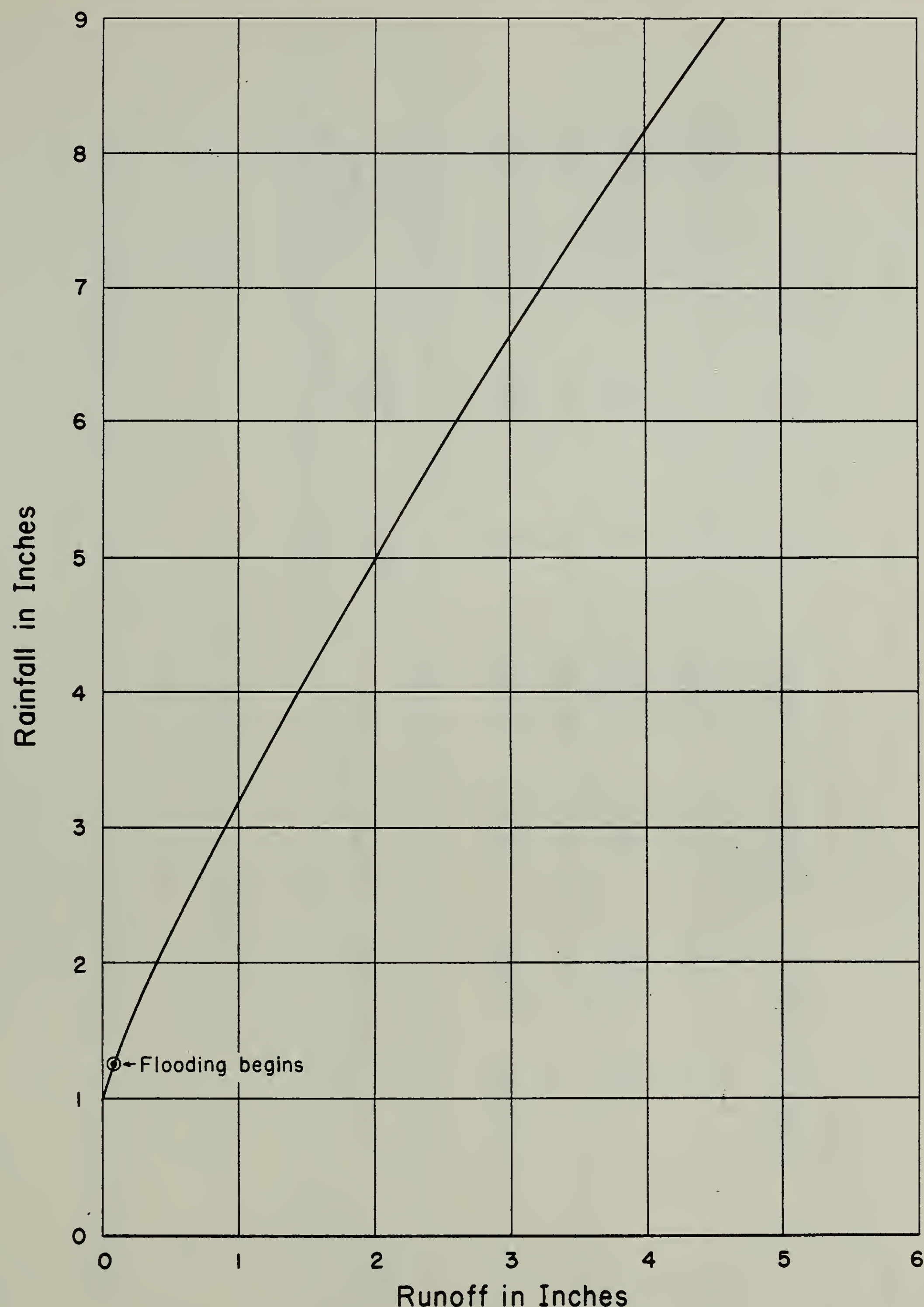

Figure 11

RAINFALL-RUNOFF RELATIONSHIP
PRESENT CONDITION
WILDHORSE CREEK
WASHITA RIVER WATERSHED - OKLAHOMA & TEXAS

W.C.B. 11-30-50 4-R-7950-7

AGR-SCS-FORT WORTH, TEX. JUNE, 1951

Table 13 - Classification of Storms in the Series, Present Condition

Wildhorse Creek

Washita River Watershed

No. of Storms	Frequency Years	Average Annual Acres Flooded				Percent of Number	Percent of Acres	Range in Inches of Runoff
		0 - 1'	1' - 3'	3' ≠	Total			
93	less than 1	18,995	4,852	194	24,041	79	54	0.09 - 0.99
21	1-5	6,716	9,465	785	16,966	18	38	1.00 - 2.75
2	5-10	471	1,343	556	2,370	2	5	2.76 - 3.70
1	10-20	236	516	510	1,262	1	3	3.71 - 4.55
Total 117	-	26,418	16,176	2,045	44,639	100	100	-

TABLE 14 - SOIL-COVER COMPLEX DATA SHEET FOR COMPUTING RAINFALL-RUNOFF RELATIONSHIP

Future Condition — Washita River Watershed — Wildhorse Watershed

(Land treatment measures applied with maximum effect)

Soil-Cover Complex	Acres	P = 1" Runoff (inches)	P = 2" Runoff (inches)	P = 4" Runoff (inches)	P = 6" Runoff (inches)	P = 8" Runoff (inches)	P = 10" Runoff (inches)
Cultivated Untreated - D&S - FT	-		.708	1.993	3.392	4.832	6.332
Cultivated Untreated - D&S - MT	-		.576	1.736	3.060	4.445	5.901
Cultivated Untreated - D&S - CT	-		.483	1.548	2.809	4.155	5.578
Cultivated Untreated - VS - FT	-		.708	1.993	3.392	4.846	6.459
Cultivated Untreated - VS - MT	-		.576	1.754	3.226	4.754	6.364
Cultivated Untreated - VS - CT	-		.507	1.817	3.315	4.850	6.459
Cultivated Treated - D&S - FT	20,843		.405	1.351	2.497	3.964	5.129
Cultivated Treated - D&S - MT	102,348		.253	.994	1.944	3.044	4.255
Cultivated Treated - D&S - CT	2,699		.151	.791	1.642	2.653	3.831
Pasture - Excellent - D&S	19,000		.010	.205	.912	1.764	2.792
Pasture - Good - D&S	142,213		.052	.508	1.262	2.184	3.242
Pasture - Fair - D&S	43,000		.316	1.170	2.235	3.431	4.717
Pasture - Poor - D&S	-		.529	1.650	2.938	4.300	5.749
Pasture - Fair - VS	7,000		.316	1.525	2.975	4.498	6.098
Pasture - Poor - VS	5,000		.529	1.678	3.141	4.672	6.275
Pasture - Fair - RB	3,815		.435	1.814	3.314	4.846	6.459
Pasture - Poor - RB	6,059		.598	1.969	3.477	5.020	6.636
Woods - Good - D&S	12,950		.010	.205	.912	1.764	2.792
Woods - Fair - D&S	8,019		.099	.644	1.455	2.421	3.546
Woods - Poor - D&S	1,000		.335	1.246	2.358	3.575	4.901
Woods - Good - VS&RB	2,922		.010	1.056	2.483	3.986	5.559
Woods - Fair - VS&RB	4,024		.106	1.359	2.815	4.324	5.914
Woods - Poor - VS&RB	3,805		.335	1.525	2.975	4.498	6.098
Miscellaneous-Roads, Urban, etc.	24,608		.813	2.246	3.772	5.325	6.959
Total Acres and Acre-inches	409,305		89,070	375,124	767,236	1,215,730	1,717,365
Total Inches Runoff	-	0.000	.218	.916	1.874	2.970	4.196

D - Deep
S - Shallow
VS - Very Shallow
RB - Rough Broken
FT - Fine textured
MT - Medium textured
CT - Coarse textured
P - Precipitation

Pasture

Excellent - 100% cover perennial species
Good - 75% cover perennial species - good litter
Fair - 50% to 75% cover perennial species - fair litter
Poor - Less than 50% cover perennial species - no litter

Woods

Good - Neither burned or grazed
Fair - Burned or grazed
Poor - Burned & grazed

precipitation, computed by table 14 is that which could be expected if every acre within the sample subwatershed received optimum treatment. This computed runoff was adjusted by a percentage factor to reflect the average conditions to be expected as a result of the applied treatment.

A curve was developed showing the average percent reduction in runoff that may be expected from a program of land treatment, figure 12. The runoff to be expected after the land treatment measures are established, for each storm in the series was computed by referring to figure 12. The area that would have been flooded by each storm in the series was computed by reference to figure 8.

By referring to table 13 and figure 12 it is evident that the surface runoff, from 79 percent of the storms in the series, may be reduced by more than 22 percent. The reduction of runoff from all storms of record for the period considered represents an additional 331,277 acre-feet of water which would be infiltrated into the watershed annually. It is estimated that 149,930 acre-feet of this amount will return to the stream as subsurface flow and that the remaining 181,347 acre-feet will percolate to ground water reservoirs, and be available for other uses. It is assumed that increased vegetation will result in higher transporation uses. However, this increase in vegetation will provide more shade, protection from winds, and litter, thereby reducing the losses due to surface evaporation. This would in effect change the present evaporation-transpiration relationship but may not materially change the total use of water by these two factors. This assumption is based on the results of experiments conducted by scientists making studies of the transpiration and evaporation relationships under various conditions. 1/

1/ Annual Report of the Southwestern Forest & Range Exp. Station, 1946, p. 11
T/ The Hydrology of a Small Area Near Auburn, Alabama, USDA-SCS, Sept. 1949

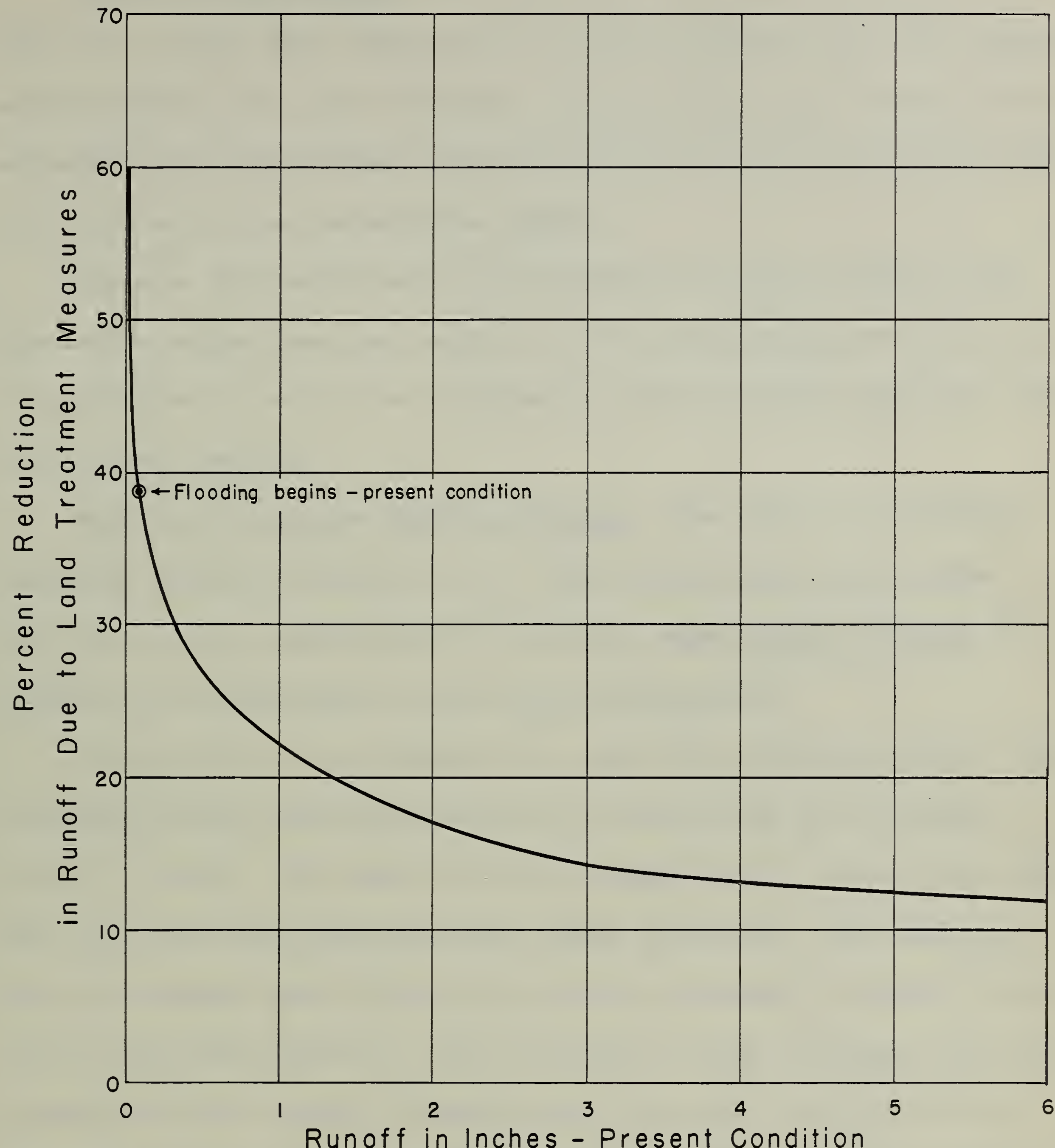

Figure 12

PERCENT REDUCTION IN RUNOFF
DUE TO
LAND TREATMENT MEASURES

WILDHORSE CREEK

WASHITA RIVER WATERSHED-OKLAHOMA & TEXAS

L.A.K. 11/30/50 4-R-7950-8

With the Going Program: The benefits due to the acceleration of the going program were based on the flooding expected after the complete establishment of the land treatment measures, minus the flooding to be expected with land treatment measures applied at the going program rate up to the end of the installation period.

The area that would have been flooded by the storm series, with the land treatment measures applied by the going program at the end of the installation period, was computed by the same method explained under the previous heading.

With the Recommended Modified Program: The system of floodwater retarding structures located by the field survey party and designed according to the specifications referred to under Design Criteria was assumed to be constructed on the sample subwatershed.

The percent of the drainage area, above the reference section, not draining through retarding structures was multiplied by incremental values of runoff. The peak discharge corresponding to these values was read from the runoff-peak discharge curve, figure 10. The discharge from the release tubes corresponding to the incremental values of runoff was read from figure 9. The two values of peak discharge thus computed were added together to obtain the total peak discharge at the reference section. These modified flows were referred to each section rating curve and stage-area inundated curve previously described, and the area flooded by depth increments downstream from the retarding structures was computed. The area which was flooded upstream from the retarding structures was added to the area flooded downstream from the retarding structures to develop the depth area inundated curves shown on figure 13. The flood plain within the retarding structure sites is

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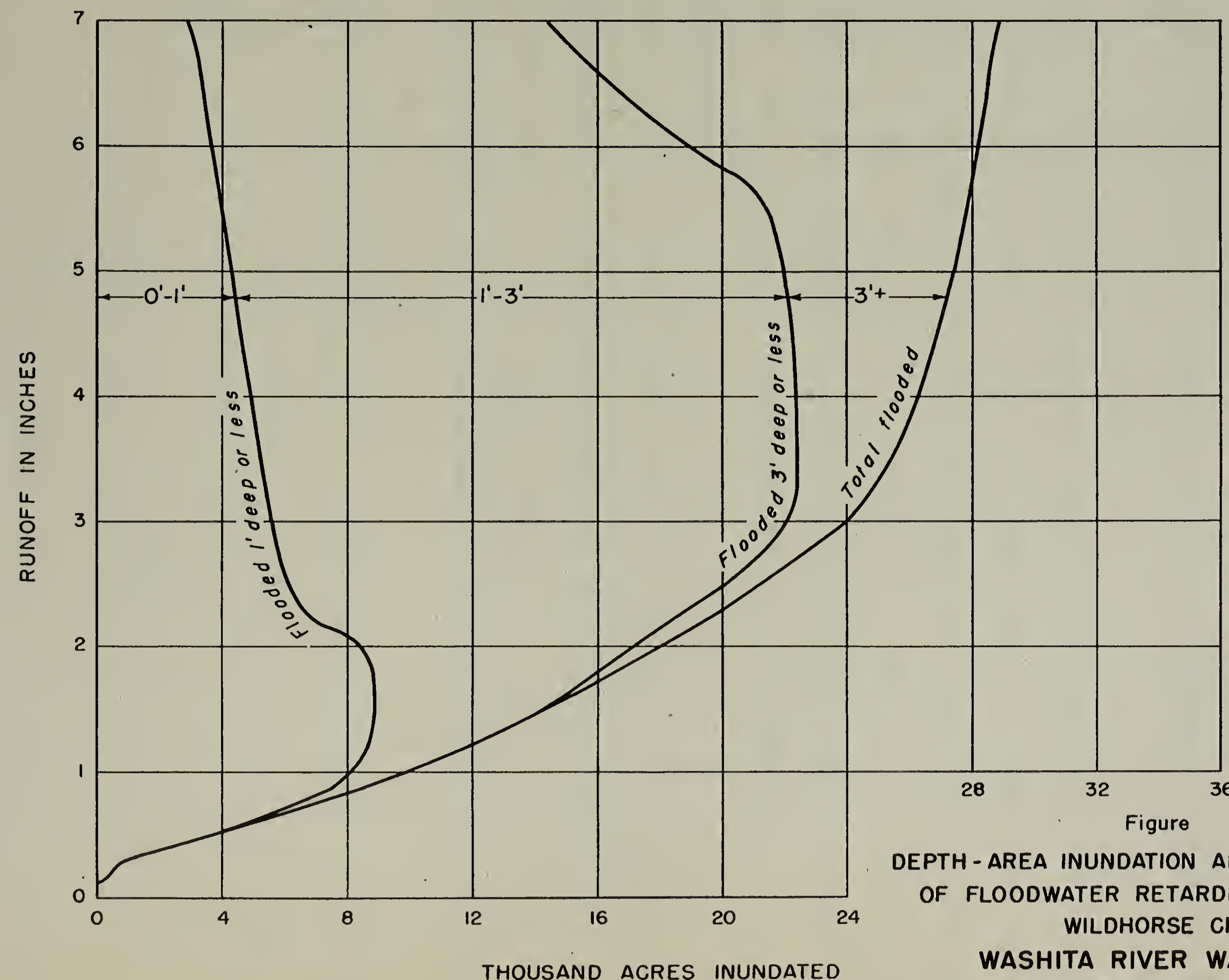

Figure 13

DEPTH - AREA INUNDATION AFTER INSTALLATION OF FLOODWATER RETARDING STRUCTURES
WILDHORSE CREEK

WASHITA RIVER WATERSHED
OKLAHOMA AND TEXAS

7-19-51 M.D.G. 4-R-7950-18

AGR-SCS-FORT WORTH TEX JULY, 1951

not included in these curves. The loss of net income from the flood plain area within the retarding structures is accounted for on page 125 of Appendix VI.

Flooding on the Washita River

Present Condition: Data for a series of historical floods on the Washita River were obtained from the Tulsa District of the Corps of Engineers. These data consisted of rating curves for the cross-sections at the stream gages and two other reference sections; stage-area inundation curves for each of the 25 reaches shown on figure 14; and the peak discharge, stage, and duration of flooding for each flood in the series.

The criteria explained on page 84 of Appendix IV were applied to the flood series and only those storms judged to be damage-producing were retained.

The 25 reaches were divided into nine groups and the stage-area inundated curves for each reach within the groups were related to a reference cross-section. The flooding within each reach was read from the stage-area inundated curves and summed to obtain the total area flooded for each storm in the series.

With Land Treatment Measures: A runoff-peak discharge curve was developed for each reference section. The volume of runoff from the drainage area between the reference sections and from the total drainage area above each reference section was computed for each storm in the flood series. The reduction in the volume of runoff from the intervening area, due to the land treatment measures was computed by applying the proportional contribution of each tributary area represented. The modified volume of runoff from the intervening area was added to the modified volume of runoff entering the upstream end of the reach. The

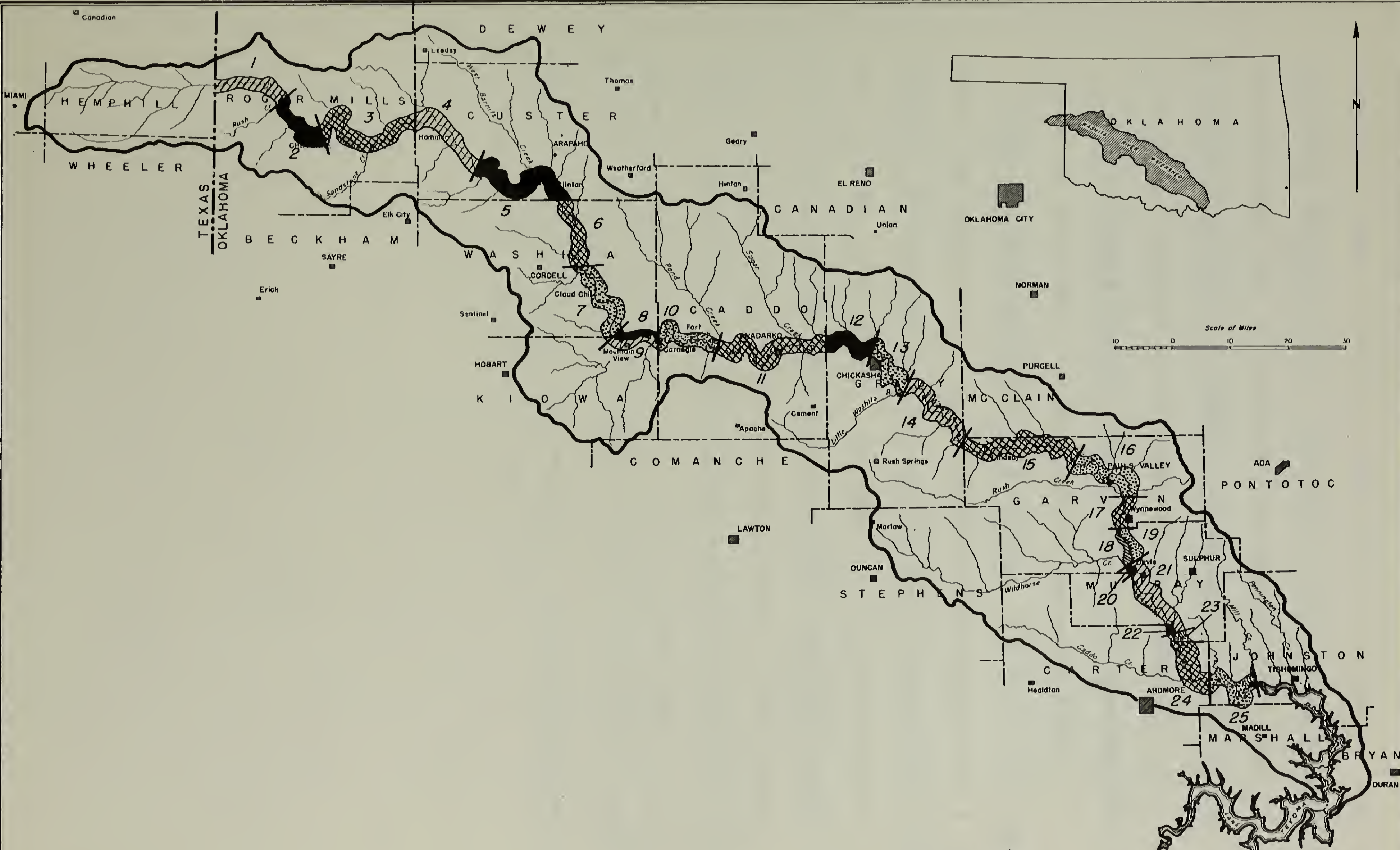

Figure 14

MAIN STEM REACHES

WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS

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CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

COMPILED	TRACED	CHECKED	DATE
G.G.C.	D.S.		6-18-51

Source: Department of the Army, Corps. of Engineers.

4-N-7950-15

AGR-SCS-FORT WORTH, TEX. JUNE 1951

corresponding peak discharge at the reference section was read from the runoff-peak discharge curve. The rating curve and stage-area inundated curve were then used to determine the acres flooded within the reach. The modified duration of flooding corresponding to the reduced volume of runoff was computed for each storm in the series.

With the Going Program: The flooding to be expected with the going program was computed by the same methods described above.

With the Recommended Modified Program: The peak flow remaining after installation of the land treatment measures was used as a base for computing further reduction in peak flow due to installation of water-flow retardation structures. The peak discharge that would be produced by the runoff from the uncontrolled drainage area was computed and added to the discharge from the drawdown tubes of the retarding structures. The individual section rating curves and stage-area inundated curves were used to determine the flooding within each reach for all storms in the series. The modified duration of flooding, increase or decrease, corresponding to the reduction in peak discharge was computed for each reach for all floods in the series.

APPENDIX IV

WATERSHED FLOOD PROBLEMS AND RELATED DAMAGES

Floodwater and sediment damage in the watershed results from uncontrolled runoff and accelerated erosion. Without watershed treatment flooding can be expected to increase in frequency, magnitude and severity of damage.

Two general types of storms produce floods in the watershed. Local storms covering about 100 to 400 square miles result in floods on the tributaries. Floods on the main stem resulting from these local storms are usually of short duration and effect only a small portion of the main stem. General storms, covering large portions of the watershed, result in severe flooding on the main stem of the river as well as flooding on the larger tributaries.

DESCRIPTION OF FLOOD DAMAGES

Tributaries of the Washita River have a high frequency of flooding, with some tributaries averaging as high as nine floods per year. A large number of the floods would be classed as small floods but nearly all are damage-producing floods. Flooding on the main stem of the Washita occurs less frequently than on the tributaries, the highest frequency of flooding on any reach being slightly in excess of two floods a year.

Due to the large aggregate area subject to flooding and the high frequency of flooding, most of the floodwater and sediment damage in the Washita River Watershed occurs on the tributaries. Table 15 shows areas subject to flooding and annual flood damages by tributary areas and main stem.

Table 15 - Area Subject to Flooding and Average Annual Flood Damages, 1949 Prices, by Tributary Areas and the Main Stem

Washita River Watershed

Tributary Areas 1/	Area Subject to Flooding	Average Annual Floodwater and Sediment Damage			
		Under Present Conditions	With Going Land Treatment Measures	With Complete Land Treatment Measures	With Modified Recommended Program
	(Acres)	(Dollars)	(Dollars)	(Dollars)	(Dollars)
1	5,998	25,248	24,313	19,613	19,613
2	3,040	12,801	12,322	9,941	9,941
3	22,208	299,452	269,413	239,040	30,822
4	32,716	761,570	674,582	571,420	127,268
5	21,396	277,759	231,026	178,141	92,071
6	73,957	1,707,759	1,585,643	1,134,754	484,960
7	78,485	870,075	769,453	652,220	300,313
8	22,891	249,433	230,026	196,039	21,206
9	4,456	8,647	7,012	6,086	6,086
Sub-total	265,147	4,212,385	3,803,790	3,007,254	1,092,226
Main Stem	111,960	1,321,569	1,099,783	871,973	425,238
Total	377,107	5,533,954	4,903,573	3,879,227	1,517,464

1/ For location of tributary areas see figure 6, page 42.

The larger part of the total floodwater and sediment damage in the watershed is suffered by agricultural interests. Though the damage suffered in urban areas is small in comparison to agricultural damage, urban areas are also adversely affected by the damage suffered by agricultural interests. Agricultural damage constitutes a larger proportion of the total floodwater and sediment damage on the tributaries than on the main stem.

Floodwater Damages

Of the total floodwater and sediment damage $4,536,992, or 82 percent, is floodwater damage. Floodwater damage includes crop and pasture damage, other agricultural damage, land damage, and nonagricultural damage. Approximately $3,954,705, or 87 percent of the total floodwater damage, is agricultural damage.

Other floodwater damages which were considered but not evaluated include insecurity of income, disruption of public service, damage to recreation and wildlife, and costs of relief and sanitation.

Crop and Pasture and Other Agricultural Damage: Of the agricultural floodwater damage 79 percent is crop and pasture damage and 16 percent is other agricultural damage. The concentration of floods during the growing season is a major factor contributing to the high percentage of crop and pasture damage. Damage to fences constitutes the major portion of other agricultural damage. Also included in other agricultural floodwater damage is damage to farm roads, buildings, stored crops, equipment, and livestock.

Land Damage: Flood plain scour and stream bank erosion constitutes four percent of the total floodwater damage and five percent of the total agricultural damage. Scour damage is the major floodwater damage to land on the tributaries. On the main stem stream bank erosion becomes a more serious damage, constituting the bulk of the damage to land by floodwater.

Further discussion of flood plain scour and stream bank erosion is included in the discussion of damage to land by overbank deposition in the section on valley sediment damage.

Nonagricultural Damage: Nonagricultural damage includes damage to roads and bridges, other transportation facilities and supply services, levees and other flood control installations, industrial developments, urban areas, relief expenditures, etc. For the watershed as a whole, 13 percent of the total floodwater damage is classified as nonagricultural damage. On the tributaries seven percent is nonagricultural damage while on the main stem 36 percent is nonagricultural damage. On the tributaries the major nonagricultural damage is damage to roads and bridges. The major municipal and industrial areas suffering damage are located on the main stem flood plain.

Valley Sediment Damage (Tributary Areas)

Damage to land from overbank sediment deposition constitutes 2.7 percent of the total floodwater and sediment damage and 3.2 percent of the agricultural floodwater and sediment damage. The following discussion of land damage by physiographic areas applies primarily to tributaries and includes valley sediment damage, flood plain scour and stream bank

erosion. Land damage on the main stem of the Washita River is discussed separately. For location of sedimentation studies see figure 15.

High Plains: Sedimentation conditions in the Gageby Creek Watershed are considered as typical of all other tributaries in the High Plains area. The principal damages occurring are: (1) loss of channel capacity due to filling of the channel with coarse sand and (2) overbank deposition of coarse sediment on the flood plain. Approximately 50 percent of the flood plain (1,019 acres) has been damaged by overbank deposits. Minor damages have resulted from localized swamping and some flood plain scour. Bank erosion causes a loss of about one acre annually.

Chief sediment sources are sheet and gully erosion on areas of steep, sandy, highly erodible soils.

Investigation of other small streams in the western part of Roger Mills County, Oklahoma revealed similar types and degree of damage.

Redbeds Plains: The greater part of the Washita River Watershed occurs within this physiographic subdivision. Sedimentation damages were investigated in several tributary valleys, since a wide variety of conditions are encountered. These include the rough and hilly topography of the Quartermaster shales and sandstones, the rolling hills and deep canyons of the Cloud Chief gypsiferous shales and sandstones, the massive but loosely consolidated and highly erodible Whitehorse sandstone, and the sandy rolling hills to comparatively level prairies of the Clear Fork-Wichita formation.

Sandstone Creek Watershed was selected as representative of the Quartermaster formation. The principal damages occurring are: (1)

Watershed No.	Watershed Name	No. of Studies
1	Broken Leg Creek	3
2	Sergeant Major Creek	1
3	Sandstone Creek	23
4	Cheyenne Wildhorse Cr.	3
5	East Branch of Hay Cr.	2
6	Verden Watershed	1
7	Kilgore Watershed	2
8	Prairie Dale Watershed	2
9	West Spring Creek	3
10	Owl Creek	3
11	Peavine Creek	1
12	Upper Mill Creek	2
13	Pennington Creek	3

Figure 15
KEY MAP - SEDIMENTATION STUDIES
WASHITA RIVER WATERSHED, OKLAHOMA & TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
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G. J. Foley — CARTOGRAPHIC APPROVAL; Graham W. Renfro — TECHNICAL APPROVAL

COMPILED V.H.J. TRACED M.G. CHECKED G.B. DATE 12-11-50

4-L-7950-14

Base 4-R-22

modern overbank deposition, (2) alluvial fan deposition, (3) channel filling and (4) stream bank erosion. Flood plain scour is a minor damage. The major source of sediment is active gully erosion and headward migration of valley trenches.

It is estimated that over 4,000 acres have suffered damage from deposition of infertile sediment. Land destroyed annually by stream bank erosion is in excess of five acres.

Channel filling is occurring on the lower portion of Sandstone Creek and is progressing upstream, reducing the channel capacity and causing increased damages from overbank deposition and flooding.

About six miles of channel were excavated in 1942, causing accelerated bank erosion and stream incision for a distance of approximately 2,500 feet upstream.

Barnitz Creek Watershed occurs within the outcrop of the Cloud Chief gypsum, a high sediment-producing area. Overbank deposits were found on about 62 percent of the entire flood plain of Barnitz Creek and its tributary valleys. Although the total volume of sediment found on the flood plain is high, its texture is such that little or no damage results on much of the area covered.

Channel filling in the upper part of the watershed has caused major damage by increasing flood heights, making periodic channel excavation necessary.

Bank erosion is also serious, three acres being lost annually through this process. Damage from alluvial fans and flood plain scour is minor. The chief sediment sources are: (1) sheet erosion of the extensively cultivated and steep upland fields and (2) headward

gully development in minor tributaries.

Little Washita and Sugar Creek Watersheds occur principally within the outcrop area of the Whitehorse sandstone, a very high sediment-producing area. Overbank deposition has damaged over 75 percent of the flood plain of the Little Washita River. Damaging overbank deposits were found on over 45 percent of the Sugar Creek flood plain.

Channel filling is also a major damage in both watersheds. Channel capacity loss is in excess of 50 percent. This has resulted in more frequent flooding and increased flood heights. Numerous levees have been constructed in an attempt to combat these conditions, but in many cases this action has resulted in further damage downstream. A further damage resulting from overbank deposition is swamping on several thousand acres.

Most of the sediment produced in these watersheds is derived from active sheet and gully erosion. Numerous tributaries have many large, active headwater gullies with rapidly eroding overfalls at the gully heads. Approximately 25 percent of the cultivated upland has been abandoned due to severe sheet erosion.

Wildhorse Creek drains a large area, most of which consists of sandstones and shales of the Clear Fork-Wichita formation. The Chickasha and Duncan formations outcrop in the upper portion of the drainage area. In the lower portion outcrops of the Pontotoc formation and the Arbuckle limestone occur. Damaging overbank deposits are largely confined to the upper half of the flood plain, or the Stephens County portion, and are derived principally from erosion of the Chickasha

and Duncan formations. Damages in Garvin County, or the lower half of the flood plain, consist primarily of flood plain scour and alluvial fan deposition at the edge of the flood plain. These fans are being deposited by small tributary streams. The major part of the land loss resulting from stream bank erosion occurs in the upper part of the flood plain. Overbank deposition in this area has damaged 4,718 acres of bottomland. A comparison of valley damages found during this survey and those found in the survey of 1940 revealed that an additional 1,483 acres were damaged in the ten year period. In addition, it is estimated that the percentage of damage on the remaining 3,235 acres has increased, during this period, from 10 to 25 percent.

Sheet erosion and gully development on steep valley slopes in the upper half of the drainage area are the major sediment sources.

Rainy Mountain Creek drains a large area of the Clear Fork-Wichita formation in which mature topography, having moderate to gentle slopes, predominates. The soils are fine textured and although sheet erosion rates are moderately high, resulting deposits of sediment on the flood plain are only slightly damaging in nature. Approximately 3,500 acres, or 25 percent of the flood plain, have been damaged about 10 percent by such deposits. A few small localized areas have coarser deposits and damages are somewhat higher. Flood plain scour has damaged an additional 1,200 acres. Degree of damage ranges from 10 to 25 percent. Damages by stream bank erosion are minor.

The chief source of sediment in the drainage area is sheet erosion of cultivated land. Gully and stream bank erosion are of minor significance.

Arbuckle Mountain Uplift: The greater part of the Mill Creek Watershed in the Arbuckle Mountain Uplift is underlain by limestones of the Arbuckle and Simpson formations. Pre-Cambrian granite also underlies part of the drainage area. Sediment output rates are inherently low except for localized areas of sandy soils.

Damages from overbank deposition of sediment are minor. Eight and one-half percent of the flood plain acres have suffered damage from this source. Channel filling occurs only in localized areas. Stream bank erosion is insignificant. Flood plain scour is the most extensive damage in the valley. Approximately 12 percent of the flood plain has been damaged by scour channels, with damage ranging from 25 to 100 percent. The major sediment source is sheet erosion of sandy upland soils.

Gulf Coastal Plain: The major portion of the Glasses Creek Watershed is underlain by interbedded limestones and shales of the Washita formation of Lower Cretaceous age. Small areas of Trinity sand and Goodland limestone also occur in the drainage area. Sediment rates are inherently low and damages are relatively minor. Damaging overbank deposits were found on 27 percent of the flood plain. However, nearly 50 percent of the damaged area has been damaged only 10 percent. Flood plain scour is a minor item of damage. Less than seven percent of the flood plain has been damaged by this process, the degree of damage ranging from 25 to 100 percent. Sheet erosion of the extensively cultivated lands is the major sediment source. Gully and stream bank erosion are minor contributors.

Table 16 gives a summary of damages to valley lands by sedimentation, flood plain scour and stream bank erosion by sample tributaries.

Table 16 - Summary of Damages to Valley Lands by Sedimentation, Flood Plain Scour, and Stream Bank Erosion for Tributary Sample Areas

Washita River Watershed

Name of Tributary	Physiographic Province & Subdivision	Annual Damage 3/ by Accelerated Deposition (Acres)	(Percent) 1/	Annual Damage by Flood Plain Scour (Acres)	(Percent) 1/	Annual Damage by Stream Bank Erosion (Acres)	(Percent) 1/
Gageby Creek	HIGH PLAINS	30	50	11	50	1	100
	REDBEDS PLAINS						
Sandstone Creek	Quartermaster Shale Area	102	28	4	50	5	100
Barnitz Creek	Cloud Chief Gypsum Area	191	19	N 2/	N	3	100
Rainy Mt. Creek	Wichita Area	70	10	120	15	N	N
Sugar Creek	Whitehorse Sandstone Area	169	49	106	20	2	100
Little Washita	Whitehorse Sandstone Area	338	60	N	N	N	N
Wildhorse Creek	Wichita Area	117	28	550	22	3	100
Mill Creek	ARBUCKLE MT. UPLIFT	8	50	53	46	1	100
Glasses Creek	GULF COASTAL PLAIN	15	29	20	69	N	N

1/ Percent damage is the weighted average damage of the percent damage classes.

2/ N - negligible.

3/ Including alluvial fans.

Valley Sediment Damage (Main Stem)

Sediment deposition, flood plain scour and stream bank erosion occurring in the main valley of the Washita River are significant damage problems resulting from floods in the drainage area.

Destructive deposition of sediment upon agricultural flood plains is a serious problem in Reaches 1, 2 and 3, an area extending from the Texas-Oklahoma line to the Roger Mills-Custer County line. (See figure 14, Appendix III for location of main stem reaches.) This is principally due to the sand filled channel which causes frequent overflows. Seventy-five percent of the flood plain in this area is damaged by deposition of harmful sediments. The average percent of damage exceeds 50 percent. This area also has the greatest damage by alluvial fans. Of the total 980 acres damaged by this process in the Washita valley, 555 acres occur in Reaches 1, 2 and 3.

From Reach 4 to 14, an area extending from the western line of Custer County to the Grady-Garvin County line, the greater part of the valley consists of terraces which occur at considerable heights above the stream bed, and are seldom submerged. The sediment carried by the main stream is generally finer in texture and does not entirely destroy the utility of the area upon which it is deposited. However, sixty percent of the flood plain in this area is damaged by harmful sediment, damages averaging about 50 percent. Scour damage has affected about 15 percent of the flood plain. Damages by bank erosion are relatively minor.

From Reach 14 through Reach 25, the head of Lake Texoma, the principal damage occurring is bank erosion. Of the total 150 acres

estimated to be destroyed annually by this process, 130 acres are lost in this area. Accelerated deposition of harmful sediment is also occurring in this area, particularly between Reaches 15 and 21.

Further details on location of specific areas of land damage, acres affected and degree of damage are contained in table 17.

Reservoir Sedimentation

Existing Municipal and Private Reservoirs: The Washita River arm of Lake Texoma is the only major reservoir in the drainage area. Several small reservoirs exist in the watershed, a number of which are suffering serious damage from sedimentation, figure 15.

Annual sediment accumulation per square mile of drainage area ranges from 0.5 acre-foot in Veterans Lake near Sulphur to 3.95 acre-feet in Lake Duncan. Table 18 gives pertinent information on a number of representative reservoirs in the watershed. Detailed sedimentation surveys have been made by the Soil Conservation Service on 4 of the 16 reservoirs listed in the table. Reconnaissance surveys were made on eight others. Lake Clinton, in the upper portion of the watershed, and Lake Ardmore, in the lower portion, have similar rates of annual sediment deposition per square mile of drainage area, Lake Clinton showing 2.61 acre-feet, and Lake Ardmore 2.52 acre-feet. Their similar indices of erosion should closely approach the average for headwater reservoirs in the greater portion of the intensively cultivated land in the watershed. However, studies throughout the watershed revealed that sediment contributions per square mile of drainage area may vary widely on adjacent watersheds despite similar geologic, soil and land use conditions.

Since sedimentation rates in the Redbeds Plains are unusually high, the sediment damage to water supply reservoirs needs special emphasis.

Table 17 - Summary of Damages to Valley Lands by Sedimentation, Flood Plain Scour and Stream Bank Erosion for the Main Stem of the

Washita River Watershed

Reach No.	Physiographic Province and Subdivision	Annual Damage by Accelerated Deposition 2/ (Acres)	(Percent) 1/	Annual Damage by Flood Plain Scour (Acres)	(Percent) 1/	Annual Damage by Stream Bank Erosion (Acres)	(Percent) 1/
1	HIGH PLAINS	36	57	9	72	-	-
2	" "	34	47	21	50	1	100
	REDBEDS PLAINS						
3	Quartermaster Shale Area	131	42	33	42	10	100
4	" " "	111	27	37	36	1	100
5	Cloud Chief Gypsum Area	85	28	53	37	1	100
6	" " " "	49	27	29	37	-	100
7	" " " "	78	22	49	40	1	100
8	Clear Fork-Wichita Area	18	23	17	42	1	100
9	" " " "	22	33	14	36	1	100
10	Whitehorse Sandstone Area	57	38	44	37	1	100
11	" " "	158	34	121	50	1	100
12	Chickasha Duncan Area	36	28	69	42	1	100
13	" " "	22	27	36	19	1	100
14	" " "	50	33	67	27	3	100
15	Clear Fork-Wichita Area	57	43	50	26	13	100
16	" " " "	87	42	135	28	38	100
17	" " " "	28	34	62	18	16	100
18	" " " "	16	26	38	22	4	100
19	" " " "	31	26	73	22	4	100
20	ARBUCKLE MOUNTAIN UPLIFT	16	38	40	17	4	100
21	" " "	66	50	117	34	20	-
22	" " "	5	60	1	60	-	100
23	" " "	11	30	1	40	-	100
24	" " "	51	46	51	45	13	100
25	GULF COASTAL PLAIN	36	60	61	58	15	100

1/ Percent damage is the weighted average damage of the percent damage classes.

2/ Including alluvial fans.

Table 18

Reservoirs in the Washita River Watershed

Name	Location (Nearest City)	Stream	Ownership & Purpose of Reservoir 1/	Date Completed	Drainage Area	Original Capacity	Annual Depletion of Storage	Physiographic Sub-division 2/	Original Capacity Per Sq.Mi. of Drainage	Annual Sediment Accumulation Per Sq.Mi. of Drainage	Original Cost	Source of Data
					(Sq.Mi.)	(Ac-Ft)	(Ac-Ft)		(Ac-Ft)	(Ac-Ft)	(Dollars)	
Lake Clinton	Canute	Turkey Creek	City of Clinton, M	1930	23	4,415	59.0	R. P.	192.0	2.55	600,000	Detailed Survey - 1938
Bartlett Lake	Butler		Bartlett Gas. Co.,I	1930	6.2	100	4.0	R. P.	16.0	0.7	3,000	File Data - Rate Est. 1941
Lake Duncan	Duncan	Trib.of Wildhorse	City of Duncan, M	1937	10.1	6,261	39.7	R. P.	623.0	3.95	235,000	Detailed Survey - 1950
Chisholm Trail Lake	Duncan	Clear Creek	City of Duncan, M	1949	20.1	11,856	69.3	R. P.	590.0	3.45	800,000	Detailed Survey - 1950
J. J. Harrison Lake	Lindsay		J. J. Harrison, R	1932	0.8	349	4.0	R. P.	431.0	4.6	11,000	Reconnaissance Survey 1950
Byars Club Lake	Byars		Gulf,Colo.&S.F.RR,R	1904	2.6	507	3.0	R. P.	199.0	1.2	20,000	Reconnaissance Survey 1950
Veterans Lake	Sulphur	Trib.of Rock Creek	City of Sulphur, R	1938	3.4	1,400	1.7	A. M.	412.0	0.5	55,000	File Data-W. L. Benham,W.P.A.
Carter Lake	Madill	Glasses Creek	City of Madill, M	1936	1.7	865	2.15	AM & GCP	508.0	1.26	35,000	Reconnaissance Survey 1949
Madill City Lake	Madill	Glasses Creek	City of Madill, M	1907	0.9	245	1.62	AM & GCP	272.0	1.8	7,000	Oklahoma Pl. & Resources Board
Ardmore Club Lake	Ardmore	Trib. of Caddo	City of Ardmore, R	1922	4.1	1,797	10.0	A. M.	433.0	2.38	60,000	Detailed Survey - 1938
Ardmore City Lake	Ardmore	Trib. of Caddo	City of Ardmore, M	1902	2.0	3,000	5.0	A. M.	1,500.0	2.4	200,000	Reconnaissance Survey 1938
Mountain Lake	Ardmore	Hickory Creek	City of Ardmore, M	1923	15.0	4,000	38.0	A. M.	266.7	2.5	300,000	File Data - Rate Est. in 1941
Chickasaw Lake	Ardmore	Trib.of Sand Creek	City of Ardmore, R	1908	.4	300	1.0	A. M.	83.3	2.5	8,000	File Data - Rate Est. in 1941
Lake Texoma	Denison	Red River	U.S. Corps of Engineers, FC-P-R	1942	28,971	5,859,000	22,700.0	Entire Red River	153.0	0.78	55,500,000	U.S.E.D. - Detailed Survey - 1948
Lake Texoma 3/		Washita River			7,864	1,792,647	9,800.0	Entire Washita River	230.1	1.29		U.S.E.D. - Detailed Survey - 1948

1/ Reservoir purpose abbreviations:
M - Municipal Water Supply
P - Power
FC - Flood Control
R - Recreation
I - Industrial

2/ Abbreviations:
RP - Redbeds Plains
AM - Arbuckle Mountains
GCP - Gulf Coastal Plain

3/ Washita River Contribution to Lake Texhoma

The loss or limitation of such reservoirs may become serious if protective measures are not taken to control sediment deposition, since additional favorable sites are not abundant.

Lake Texoma: Lake Texoma is impounded by a dam on the Red River valley about 5 miles northwest of Denison, Texas. A major arm of this reservoir occupies a considerable area of the lower part of the Washita River valley and its original capacity was 1,792,647 acre-feet as compared to a total of 5,859,000 acre-feet for the entire reservoir. A detailed sedimentation survey, made by the U. S. Corps of Engineers in 1948, showed that the Washita River arm of the reservoir has sustained an average annual capacity loss of 0.55 percent by sedimentation during the 6.2 year period. This is somewhat higher than the annual capacity loss of the entire reservoir (0.39 percent). It should be noted that the average annual runoff from the Washita River Basin was nearly 30 percent higher than the average, and that the annual runoff during this period from the main Red River Basin was somewhat below normal. The average annual sediment accumulation per square mile of drainage area during the life of the lake has been 1.29 acre-feet in the Washita arm as compared with 0.78 acre-feet for the entire reservoir. Despite the variation from normal runoff rates in the two parts of the Red River drainage, the indication of higher erosion rates in the Washita River portion is substantiated by surveys of erosion rates and of rates of sedimentation in smaller reservoirs.

Indirect Flood Damage

In addition to the obvious direct damage, numerous indirect flood losses are incurred in the watershed. Among the more evident forms of indirect flood damage are interruption of traffic, industry and public

services; loss of business in the community from the reduction of agricultural production; interruption of business and gainful occupation; and numerous other disturbances in social and economic relations in the region of the flooded areas. Indirect damage in the watershed is estimated to be approximately $663,789 annually or 12 percent of the total floodwater and sediment damage.

Summary of Floodwater and Sediment Damage

Table 19 shows the floodwater and sediment damages by type of damage for the watershed (1) under present conditions, (2) with continuation of the going program at the present rate, (3) with complete land treatment program, and (4) with the recommended modified program. Of the total estimated floodwater and sediment damage under present conditions 56.7 percent is damage to crops and pasture, 11.5 percent is other agricultural damage, 10.5 percent is nonagricultural damage, 5.7 percent is damage to land, 3.6 percent is sediment damage to reservoirs, and 12.0 percent is indirect damage.

METHODS OF ESTIMATING FLOOD DAMAGES

In order to properly evaluate the independent measures, the watershed was divided into nine subdivisions or tributary areas, figure 6, Appendix III. Estimates of average annual floodwater and sediment damages were made for each of the tributary areas and main stem under present conditions, with the going land treatment program, with the complete land treatment program, and with the recommended modified program. With the exception of sediment damage to reservoirs, the estimates of damages in the tributary areas and main stem were based on studies of nine representative sample tributaries and twenty-five main stem reaches. Estimates of sediment damage to reservoirs were made for each reservoir and included

Table 19 - Average Annual Floodwater and Sediment Damage 1/

Washita River Watershed

Type of Damage	Average Annual Damage			
	Under Present Conditions	With Going Land Treatment Program	With Complete Land Treatment Program	With Modified Recommended Program
	(Dollars)	(Dollars)	(Dollars)	(Dollars)
FLOODWATER DAMAGE				
Crops and Pasture	3,136,802	2,835,131	2,278,400	858,066
Flood Plain Scour	109,154	97,857	81,874	34,900
Stream Bank Erosion	74,634	74,634	74,634	74,634
Other Agricultural	634,115	543,172	409,314	124,329
Nonagricultural	582,287	486,696	360,032	108,689
Sub-total	4,536,992	4,037,490	3,204,254	1,200,618
SEDIMENT DAMAGE				
Valley Sediment Deposition	130,997	112,524	92,491	51,419
Reservoirs	202,176	159,781	111,004	87,850
Sub-total	333,173	272,305	203,495	139,269
INDIRECT DAMAGE	663,789	593,778	471,478	177,577
Total Average Annual Damage	5,533,954	4,903,573	3,879,227	1,517,464

1/ 1949 Prices.

in the appropriate tributary area. All estimates of damages were based on 1949 prices.

Floodwater Damage

Crop and Pasture Damage: Percent damage factors for various crops by months and depths of flooding were developed. The percent damage factors for each crop reflect the following: (1) the difference between the value per acre of the undamaged crop and its value after flooding; (2) expenses not incurred in growing or harvesting the crop; (3) extra cultivation cost caused by the flood; (4) cost of producing an alternate crop when applicable; and (5) the gross value of the alternate crop. The percent damage factors for each crop by months were weighted by the frequency of flooding in each month and a weighted seasonal average percent damage factor determined for each sample area. The percent damage factors for Wildhorse Creek sample tributary are shown in Table 20.

For the main stem flood plain of the Washita River crop damage curves as developed by the Corps of Engineers were used. These curves were developed in about the same general manner and reflect the same items as the percent damage factors used on the tributaries. The damage curves as developed by the Corps of Engineers allow for variation in damage by duration of flooding instead of by depth of flooding. On the main stem where duration is a more important consideration than depth or velocity these curves are more applicable than the percent damage factors developed for the tributaries.

On the tributaries the major land uses and the percentage of cultivated land occupied by each major crop was determined from surveyed valley cross-sections and field schedules. No significant variations

Table 20 - Percent Damage to Crops and Pasture by Flood Depth

Intervals and Seasons

Wildhorse Creek, Washita River Watershed

Crop	Flood Depth (Feet)	April May June (Percent)	July, August September October (Percent)	November, December January, February March (Percent)
Cotton	0 - 1.0	27.6	29.5	3.2
	1.1 - 3.0	43.0	44.1	6.6
	3.1 & Over	53.0	57.7	11.2
Corn	0 - 1.0	30.0	17.7	4.8
	1.1 - 3.0	47.2	35.6	9.0
	3.1 & Over	60.8	53.9	13.1
Barley, Oats,	0 - 1.0	34.3	5.0	3.9
and Wheat	1.1 - 3.0	50.8	11.8	9.3
	3.1 & Over	60.8	16.9	23.8
Alfalfa	0 - 1.0	16.8	16.5	7.1
	1.1 - 3.0	24.6	20.4	11.0
	3.1 & Over	46.3	27.6	15.3
Sorghum	0 - 1.0	25.4	23.7	5.4
	1.1 - 3.0	32.5	34.8	10.9
	3.1 & Over	48.9	49.4	12.9
Meadow	0 - 1.0	22.6	20.2	0.0
	1.1 - 3.0	26.9	31.4	9.6
	3.1 & Over	41.1	41.1	9.9
Broomcorn	0 - 1.0	27.3	.6	0.0
	1.1 - 3.0	51.0	34.2	.1
	3.1 & Over	56.1	34.4	.3
Pasture	0 - 1.0	11.3	5.6	6.0
	1.1 - 3.0	19.3	9.2	8.0
	3.1 & Over	21.3	11.9	10.0

in land use at different elevations were found on the cross-sections. Yields on the tributaries were also obtained from the field schedules. Land use and crop yields for the main stem reaches were furnished by the Corps of Engineers.

For the tributaries the yields were multiplied by the 1949 prices to determine the damageable value per acre for each crop. The composite damageable value of crops and pasture for Sugar Creek Sample tributary is shown in table 21. The seasonal percent damage factor was applied to the damageable value for each crop and weighted by the percent of each crop in the flood plain to determine the seasonal composite per acre damage. The composite per acre crop and pasture damages by seasons and depth of flooding for Sugar Creek are shown in table 22.

For each sample watershed the hydrologist furnished the flood series used, giving for each flood the date of occurrence and acres flooded by depths under present conditions, with the going land treatment program, with complete land treatment, and with the recommended modified program. The acres in each depth interval for each flood were multiplied by the appropriate composite per acre damage. The damage by depths for the floods in the series were totaled and divided by the years in the series to determine the average annual damage to crops for the four conditions mentioned above.

It was recognized that a series of floods in a single year would have an effect on the damage to crops by preventing the complete restoration of damageable value between floods. Therefore, not all of the floods in the flood series were considered as being damaging. The length of time between damaging floods, in the series used, varied by seasons with the shortest interval in the spring when damageable values are

Table 21 - Composite Damageable Value of Crops and Pasture (1949 Prices) Per Acre of Flood Plain

Sugar Creek Sample Tributary

Washita River Watershed

Land Use	Flood Plain in Each Use	Unit	Yield Per Acre	Production Per Acre of Flood Plain	Value Per Unit	Value of Production
	(Percent)				(Dollars)	
Corn	6.9	Bu.	32	2.208	1.25	2.76
Cotton	12.5	Lbs. Lint	240	30.000	0.328	9.84
Sorghum, Grain	6.9	Lbs.	1,400	96.600	.0204	1.97
Sorghum, Fodder	.4	Ton	2	.008	15.00	.12
Wheat	7.6	Bu.	21	1.596	1.91	3.05
Alfalfa	19.4	Ton	3	.582	21.68	12.62
Meadow	2.6	Ton	1½	.0390	17.49	.68
Pasture	35.1	A.U.M.	2.5	.8775	2.70	2.37
Woods and Waste	5.2	-	-	-	-	-

Table 22 - Composite Crop and Pasture Damage (1949 Prices) Per Acre Flooded, by Season and Depth of Flooding
Sugar Creek Sample Tributary

Washita River Watershed

Crop	Damage-able Value Per Acre	Net Damage					
		Depth 0 - 1.0'		1.1' - 3.0'		3.1' & Over	
	(Dollars)	(Percent)	(Dollars)	(Percent)	(Dollars)	(Percent)	(Dollars)
		April, May, and June					
Corn	2.76	29.7	.82	46.6	1.29	59.8	1.65
Cotton	9.84	26.6	2.62	41.6	4.09	51.6	5.08
Sorghum	2.09	25.0	.52	32.3	.68	47.9	1.00
Wheat	3.05	33.6	1.02	50.0	1.52	63.1	1.92
Alfalfa	12.62	16.7	2.11	24.4	3.08	45.9	5.79
Meadow	.68	21.6	.15	24.1	.16	40.8	.28
Pasture	2.37	11.4	.27	19.4	.46	21.7	.51
Total			7.51		11.28		16.23
		July, August, September, and October					
Corn	2.76	16.6	.46	33.8	.93	50.8	1.40
Cotton	9.84	28.4	2.79	50.6	4.97	56.2	5.53
Sorghum	2.09	21.6	.45	34.0	.71	48.0	1.00
Wheat	3.05	2.3	.07	8.6	.26	11.9	.36
Alfalfa	12.62	15.2	1.92	18.9	2.39	23.7	2.99
Meadow	.68	17.2	.12	30.3	.21	38.8	.26
Pasture	2.37	15.2	.36	18.9	.45	23.7	.56
Total			6.17		9.92		12.10
		November, December, January, February, and March					
Corn	2.76	7.2	.20	12.8	.35	17.9	.49
Cotton	9.84	5.5	.54	9.7	.95	16.0	1.57
Sorghum	2.09	9.1	.19	13.8	.29	15.7	.33
Wheat	3.05	4.6	.14	9.8	.30	22.7	.69
Alfalfa	12.62	7.1	.90	11.0	1.39	14.3	1.80
Meadow	.68	0	0	9.9	.07	12.4	.08
Pasture	2.37	6.0	.14	8.0	.19	10.0	.24
Total			2.11		3.54		5.20

subject to restoration by replanting or by use of alternate crops. Further adjustment was made to take into account the fact that often only partial restoration of damageable value is made prior to a succeeding flood.

Flood Plain Scour: The physical land damage due to scour was determined by reconnaissance, on a cross-section basis, in the stream valleys. It was estimated that scour damage for the Washita River Watershed occurs in about a ten-year cycle from original damage to recovery. Also, the amount of damage is not increasing appreciably in most areas but has tended to reach a state of equilibrium. No adjustment was made in crop and pasture damage estimates for damage due to scour, because estimates of yield are based on conditions existing at the present time, inclusive of scoured areas.

The report of the damage appraisers listed the acreage damaged and the degree of damage. The following calculations are illustrative of the procedure used in determining scour damage to land under present watershed conditions.

What is the [illegible] numerical [illegible]

Scour Damage to Land
Rainy Mountain Sample Watershed

84 acres damaged annually by 10 percent

36 acres damaged annually by 25 percent

$29.80 - annual per acre value of production less variable costs (variable costs are those production costs that vary with difference in yield.)

10 percent of $29.80 x 84 = $250.32 net value of production loss on area damaged 10 percent, year of original damage.

25 percent of $29.80 x 36 = $268.20 net value of production loss on area damaged 25 percent, year of original damage.

$250.32 + $268.20 = $518.52 net value of production loss on total area, year of original damage.

4.723 = present worth of 1 decreasing at a constant annual rate to 0 in a 10-year period.

4.723 x $518.52 = $2449, average annual scour damage.

An index of flooding was used to determine scour damage under future watershed conditions. The total acreage flooded during the period of record under present conditions was taken as 100 percent. Total acres flooded with the going land treatment program, with complete land treatment measures, and with the recommended modified program were expressed as percentages of the present acres flooded. The present damage was then multiplied by these percentages to derive the damage under future treated conditions.

Stream Bank Erosion: Estimates of the acres of flood plain land damaged annually by stream bank erosion were based on reconnaissances of the stream valleys and on valley cross-sections. The annual loss of net income was capitalized to determine the annual value of the damage. As the annual damage from stream bank erosion is relatively small and no special measures for alleviation of the damage appear feasible at this time, future estimates of damage are assumed to be the same as at the present. Loss of production in the future from this source was considered in estimating crop and pasture damage.

Nonagricultural Damage: On the sample tributaries, damage to roads and bridges constitutes the major portion of the nonagricultural damage. Road and bridge damage was based on estimates of county and state road officials and inspections of the damage areas by flood damage appraisers. Other types of nonagricultural damage such as damage to urban areas and industrial installations were based on field contacts with local residents and company representatives.

Nonagricultural damage was related to size of flood and curves were constructed showing the amount of damage by percent of the flood plain inundated. Structural loss curves for main stem reaches were furnished by the Corps of Engineers. The amount of damage for each sample tributary and main stem reach for floods in the flood series used was read from these curves for the various watershed treatment conditions. The total damage was divided by the years in the period of record used to determine the average annual damage.

Sediment Damages

Valley Sediment Damage: The physical damage to land by overbank deposition of sediment for the sample tributaries and main stem reaches was determined by valley reconnaissance on a cross-section basis. The damage appraisers determined the average acres, by damage classes, damaged annually and these estimates of present damage were used as a basis for estimating expected future damage.

Relatively large areas of most of the tributary flood plains are damaged by sediment annually yet the land use and present yields indicate that the tilth and fertility have been somewhat maintained by special farming operations and measures. Expenses for extra field operations, fertilizer, green manure crops, and foregoing of income, etc., varying in amounts and period of application by degree of damage from sediment, were treated as capital expenditures and brought back to present worth.

On the main stem, with the broader flood plain areas where often the major portion of fields are damaged, and with land use and yields at present reflecting a more drastic reduction in fertility, the loss of net income on the area damaged annually was capitalized to determine

the average annual damage. Yields used in determining crop damage, as furnished by the Corps of Engineers, appeared to be sufficiently low to reflect the fact that damageable value of crops will be reduced by damage to land. Therefore, no additional adjustment was made in crop damage.

Estimates of valley sediment damage in the future with varying watershed treatment conditions were based on reductions in acres flooded, reduction in sediment output rates, area behind floodwater retarding structures, and the sediment trap efficiency of floodwater retarding structures.

Reservoir Sedimentation: The procedure used to determine the present volume of sediment deposition in the Washita River Watershed is discussed in the description of sediment damage to reservoirs. The "straight line" method was used in evaluating this damage as illustrated for Lake Duncan:

1.	Adjusted cost per acre-foot of total storage	$76.00
2.	Volume of sediment deposited annually with present watershed conditions	39.7 acre-feet
3.	Estimated volume of sediment deposited annually with the going land treatment program	32.4 acre-feet
4.	Estimated volume of sediment deposited annually with the complete land treatment program	19.8 acre-feet
5.	Estimated volume of sediment deposited annually with the recommended modified program 1/	19.8 acre-feet
6.	Average annual damage present	$3,017.00
7.	Average annual damage with going land treatment program	$2,462.00
8.	Average annual damage with the complete land treatment program	$1,505.00
9.	Average annual damage with the recommended modified program 1/	$1,505.00

1/ Sediment damage with the complete land treatment program and with the recommended modified program were the same since no floodwater retarding structures are recommended above Lake Duncan.

APPENDIX V

THE RECOMMENDED MODIFIED PROGRAM

INTRODUCTION

The recommended modified watershed treatment program for the Washita River Watershed has been developed with the primary objectives of alleviating floodwater and sediment damage. Therefore, only those measures and practices that contribute directly to runoff and waterflow retardation and erosion control are included in the recommended modified program. Measures and practices for the primary purpose of increasing production of crops, forage, or timber are not included. However, many of the measures included as watershed needs increase the production of crops, forage and timber, and produce other beneficial effects even though they are included primarily for reductions in runoff and erosion.

To assist in the analysis of the effects and costs of measures and practices or works of improvement, the following grouping was made:

1. Those parts of the going agricultural programs in the watershed which were deemed of primary importance to the objectives of the Flood Control Act.
2. The modified program recommended in this report, which consists of:
   (a) The acceleration, intensification, or adaptation of portions of the going program to the extent necessary to achieve flood control objectives. Measures in this portion of the recommended modified program are called land treatment measures.
   (b) Additional measures not now regularly installed, but considered necessary to complete a balanced runoff and

waterflow retardation and erosion control program for the watershed. The measures contained in this portion of the modified program are called independent measures.

Procedure for Determining Needed Land Treatment Measures

Conservation Measures on Openland: The Conservation Needs Inventory developed by Soil Conservation Service technicians in 1949 was used as a base for working out the needed conservation measures for the watershed. The only measures considered were those yielding substantial reductions in runoff and erosion. Total needs for the watershed were developed by problem areas in soil conservation.

From records of soil conservation districts in the watershed an estimate was made as to the amounts of practices or measures which had been applied to date. These amounts were subtracted from the total conservation needs in order to obtain the remaining needs.

From Soil Conservation Service and Production and Marketing Administration records the annual rate of application of the practices considered was obtained. It was assumed that the present annual rate of application would continue, and the amounts of practices that would be applied in 15 years were determined. These amounts were subtracted from the total conservation needs in order to determine the additional amounts of practices needing to be applied in order to complete the conservation job in 15 years. See table 23.

The total cost of applying the measures was estimated by Production and Marketing Administration officials and Soil Conservation Service technicians. Amounts of ACP payments on the measures included in the recommended modified program were furnished by the Production and Marketing Administration.

Table 23 - Showing the Total Land Treatment Job, the Going Program and

The Recommended Modified Program

Washita River Watershed

Measure	Unit	(1) Total Land Treatment Job	(2) The Going Program	(3) Recommended Modified Program (1) - (2)
Terraces	Miles	85,030	51,833	33,197
Field Diversions	Miles	6,170	3,586	2,584
Cover Crops	Acres	1,503,000	437,781	1,065,219
Contouring Alone	Acres	33,300	22,400	10,900
Strip Crops	Acres	109,400	4,100	105,300
Liming Grassland & Legumes	Acres	248,000	135,920	112,080
Fertilizing Grassland & Legumes	Acres	845,800	304,485	541,315
Seeding Grassland	Acres	690,800	456,062	234,738
Fencing Grassland	Miles	2,761	1,624	1,137
Gully Control	Acres	111,000	24,500	86,500
Improved Fire Protection	Acres	492,000	71,370	420,630
Public Acquisition	Acres	328,100	-	328,100
Farm and Group Waterways	Miles	3,500	940	2,560
Grade Stabilizing Structures	Each	3,600	-	3,600

Public Acquisition: The need for Federal acquisition of 328,100 acres of eroded submarginal farmland as recommended in House Document No. 275, 78th Congress, 1st Session, 1/ was substantiated by a re-survey of the area in 1946. By a detailed reconnaissance survey three categories of purchase needs were mapped as follows:

1. Concentrated Purchase

2. Scattered Purchase

3. Occasional Purchase

Tract selections were made in the concentrated purchase area in order to determine the feasibility of purchase.

Treatment needs for the 328,100 acres of proposed public purchase were developed by the Land Management Division of the Soil Conservation Service, using experience gained on Land Utilization projects as a guide.

Procedure for Determining Needed Independent Measures

Amounts of independent measures needed were obtained from actual surveys of nine sample watersheds covering approximately 1,297,000 acres. Detailed operations work plans have been developed for five of these watersheds, covering 495,000 acres and the information contained in these plans on amounts and costs of measures is reliable.

In order to determine overall watershed needs for independent measures, the amounts of measures for the nine sample tributaries were expanded by tributary watersheds (figure 6, Appendix III).

Recommended Land Use Adjustments and Conservation Practices

Present land use and poor cultural practices have created a serious watershed problem. Much of the openland has been over-cropped, over-grazed

1/ Watershed of the Washita River (Oklahoma and Texas)

and otherwise mismanaged, and most of the blackjack-post oak savanna has been burned and over-grazed. These practices have created a condition of inadequate cover which results in increased water runoff and sediment output. This condition can be corrected, to a large degree, by land use adjustments in the watershed and by the application of needed conservation practices to all lands.

The following overall land use adjustments and conservation practices are recommended for the watershed: 1/

1. Improved cropping practices such as contour cultivation, crop rotation, stubble mulch tillage, and the use of green manure and cover crops on 1,795,000 acres of cropland.
2. Conversion of 628,000 acres of eroded crop and idle land to permanent grassland.
3. Improved fire protection, grazing control and cover improvement on 2,953,000 acres of grassland and 492,000 acres of blackjack-post oak savanna.
4. Public acquisition and development of 328,100 acres of submarginal watershed land.

It is recommended that these land use adjustments and practices be placed in effect as promptly as is feasible. Calculations are based on an estimated installation period of 15 years.

THE RECOMMENDED MODIFIED PROGRAM

The following sections describe the measures which are included in the recommended modified program. Installation costs include the cost of the first application or construction. Maintenance of practices and measures or works of improvement on Federally-owned land is a Federal

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1/ These figures cover total planned changes, some of which will be accomplished under going programs.

responsibility, but on private land it is considered the responsibility of local or private interests. In the latter case the estimated costs are shown as non-Federal, but it is recognized that the Department of Agriculture has responsibilities to see that the maintenance is carried out to the extent that the going programs of the Department cannot adequately meet these requirements of maintenance. The Secretary of Agriculture may request funds under appropriate authorities for carrying out maintenance of these measures and practices or works of improvement.

Quantities of measures and distribution of installation costs of the recommended modified program are shown in table 24.

Annual costs of the recommended modified program are shown in table 25. These costs include the annual equivalent of the installation cost and the annual operation and maintenance cost after the installation period.

LAND TREATMENT MEASURES

The land treatment measures recommended in this report are based on the use of each acre of agricultural land within its capabilities and the treatment of each acre of agricultural land in accordance with its needs for protection and improvement. Such a program will accomplish the primary objective of runoff and waterflow retardation and soil erosion prevention, and will reduce flood and sediment damages materially.

Present land use and estimated future land use after the installation of the recommended modified program are shown by problem areas in soil conservation in table 26.

The following measures constitute watershed needs over and above those measures already established and those that will be established by going programs during the 15-year program installation period.

Table 24 - Quantities of Measures and Distribution of Installation Costs - (1949 Prices)

Washita River Watershed

Measure	Unit	Amount	Cost in Dollars: Non-Federal: Private	Cost in Dollars: Non-Federal: Public	Cost in Dollars: Federal	Cost in Dollars: Total
Terraces	Miles	33,197	1,386,509	-	3,235,502	4,622,011
Field Diversions	Miles	2,584	204,136	-	478,040	682,176
Cover Crops	Acres	1,065,219	3,814,241	-	2,590,423	6,404,664
Contour Cultivation	Acres	10,900	3,270	-	3,270	6,540
Strip Cropping	Acres	105,300	42,990	-	42,990	85,980
Liming Grasses and Legumes	Acres	112,080	336,240	-	504,360	840,600
Fertilizing Grasses and Legumes	Acres	541,315	1,890,862	-	2,835,144	4,726,006
Seeding Grassland	Acres	234,738	613,020	-	909,277	1,522,297
Fencing New Grassland	Miles	1,137	477,540	-	90,960	568,500
Gully Control	Acres	86,525	175,045	-	410,682	585,727
Improved Fire Protection	Acres	420,630	-	25,617	76,851	102,468
Public Acquisition	Acres	328,100	-	-	3,935,463	3,935,463
Development of Acquired Land	Acres	328,100	-	-	2,527,990	2,527,990
Farm and Group Waterways	Miles	2,560	268,800	-	627,200	896,000
Grade Stabilizing Structures	Each	3,600	252,000	160,000	2,108,000	2,520,000
Educational Assistance	-	-	-	355,500	355,500	711,000
Technical Services	-	-	-	-	1,843,000	1,843,000
Administration of Direct Aids	-	-	-	-	676,610	676,610
Facilitating Measuring Devices	-	-	-	-	61,800	61,800
Floodwater Retarding Structures and Appurtenances 1/						
Floodwater Retarding Structures	Each	652	4,650,000	-	34,053,000	38,703,000
Floodwater Diversions	Miles	197.4	52,140	-	105,880	158,020
Drop Structures	Each	417	70,620	34,224	1,528,144	1,632,988
Floodways	Miles	91.3	54,976	50,324	146,600	251,900
Total			14,292,389	625,665	59,146,686	74,064,740

1/ Includes Operation and Maintenance during the Installation Period.

Table 25 - Estimated Annual Costs of the Recommended Modified Program (1949 Prices)

Washita River Watershed

Measure	Unit	Amount	Annual Operation and Maintenance After Installation			Annual Equivalent of Installation Cost			Total Average Annual Cost			
				Non-Federal			Non-Federal			Non-Federal		
			Federal	Public	Private	Federal	Public	Private	Federal	Public	Private	Total
			(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Terraces	Miles	33,197	-	-	462,201	80,888	-	55,460	80,888	-	517,661	598,549
Field Diversions	Miles	2,584	-	-	20,465	11,951	-	8,165	11,951	-	28,630	40,581
Cover Crops	Acres	1,065,219	-	-	-	64,760	-	152,570	64,760	-	152,570	217,330
Contouring Alone	Acres	10,900	-	-	-	82	-	131	82	-	131	213
Strip Cropping	Acres	105,300	-	-	-	1,075	-	1,720	1,075	-	1,720	2,795
Liming Grasses and Legumes	Acres	112,080	-	-	-	12,609	-	13,450	12,609	-	13,450	26,059
Fertilizing Grasses and Legumes	Acres	541,315	-	-	-	70,879	-	75,634	70,879	-	75,634	146,513
Seeding Grassland	Acres	234,738	-	-	-	22,732	-	24,521	22,732	-	24,521	47,253
Fencing New Grassland	Miles	1,137	-	-	28,425	2,274	-	19,102	2,274	-	47,527	49,801
Gully Control	Acres	86,525	-	-	17,572	10,267	-	7,002	10,267	-	24,574	34,841
Improved Fire Protection	Acres	420,630	5,426	1,809	-	1,921	640	-	7,347	2,449	-	9,796
Public Acquisition	Acres	328,100	-	-	-	98,387	-	-	98,387	-	-	98,387
Development of Acquired Land	Acres	328,100	65,620	-	-	63,200	-	-	128,820	-	-	128,820
Farm and Group Waterways	Miles	2,560	-	-	44,800	15,680	-	10,752	15,680	-	55,552	71,232
Grade Stabilizing Structures	Each	3,600	-	4,800	70,800	52,700	4,000	10,080	52,700	8,800	80,880	142,380
Educational Assistance	-	-	-	-	-	8,888	8,887	-	8,888	8,887	-	17,775
Technical Services	-	-	-	-	-	46,075	-	-	46,075	-	-	46,075
Administration of Direct Aids	-	-	-	-	-	16,915	-	-	16,915	-	-	16,915
Facilitating Measuring Devices	-	-	20,000	-	-	1,545	-	-	21,545	-	-	21,545
Floodwater Retarding Structures and Appurtenances												
Floodwater Retarding Structures	Each	652	21,555 1/	-	313,063 2/	929,987 3/	-	189,767 4/	951,542	-	502,830	1,454,372
Floodwater Diversions	Miles	197.4	947	-	6,951	2,891	-	2,128	3,838	-	9,079	12,917
Drop Inlets	Each	419	581	417	9,427	41,733	934	2,881	42,314	1,351	12,308	55,973
Floodways	Miles	91.3	-	1,830	7,330	4,003	1,374	2,244	4,003	3,204	9,574	16,781
Increased Operating Cost to Landowners	-	-	-	-	3,510,663	-	-	-	-	-	3,510,663	3,510,663
TOTAL			114,129	8,856	4,491,697	1,561,442	15,835	575,607	1,675,571	24,691	5,067,304	6,767,566

1/ Includes $8,400 annual maintenance and $13,155 annual loss in net income in structure sites.
2/ Includes $122,000 annual maintenance and $191,063 annual loss in net income in structure sites.
3/ Includes amortization costs at 2.5 percent for 100 years ($78,662).
4/ Includes amortization costs at 4 percent for 100 years ($3,766).

AGR-SCS-FORT WORTH, TEX NOVEMBER, 1951

Table 26 - Present and Future Land Use by Problem Areas in Soil Conservation

Washita River Watershed

	High Plains	Rolling Red Plains	Reddish Prairies	Cross Timbers	Grand Prairie	Granitic Soils	Coastal Plains	Total
Present Land Use in Acres								
Cropland	4,528	1,069,030	804,907	265,229	177,057	72,656	29,791	2,423,198
Open Grazing Land	1,081	837,872	527,621	79,783	272,124	89,709	25,262	1,833,452
Blackjack-Post Oak Savanna	-	-	44,777	402,030	68,019	71,029	-	585,855
Woodland	-	-	-	-	-	-	40,693	40,693
Miscellaneous	168	29,987	77,525	14,551	10,116	16,077	1,488	149,912
Total Land Area	5,777	1,936,889	1,454,830	761,593	527,316	249,471	97,234	5,033,110 1/
Future Land Use in Acres								
Cropland	4,437	788,927	664,887	131,359	135,448	48,163	22,232	1,795,453 - 627,745
Open Grazing Land	1,172	1,117,975	667,641	213,653	313,733	114,202	33,124	2,461,500 + 628,048
Blackjack-Post Oak Savanna	-	-	44,777	402,030	68,019	71,029	-	585,855 same
Woodland	-	-	-	-	-	-	40,390	40,390 - 303
Miscellaneous	168	29,987	77,525	14,551	10,116	16,077	1,488	149,912 same
Total Land Area	5,777	1,936,889	1,454,830	761,593	527,316	249,471	97,234	5,033,110

1/ 61,930 acres occupied by Lake Texoma must be added to the land area, making a total area of 5,095,040 acres.

shifts 627,745 / 303 / 628,048 to grazing land

Terraces

It is estimated that 33,197 miles of terraces will be required on 498,000 acres of cropland in the watershed. All land suitable for cultivation subject to water erosion, except deep sandy soils, will be terraced. By decreasing the length of slope over which runoff water travels, terraces greatly reduce sheet erosion and the development of gullies. The low velocity at which runoff water flows along the terrace channel reduces the load of sediment which it can carry. Quantities of terraces required are based on the protection of 10 to 18 acres per mile of terrace.

The total cost of installing terraces is $4,622,000. The average cost of terracing an acre of land is $9.28. The annual cost of maintenance after installation is estimated at 10 percent of the construction cost.

Field Diversions

About 2,584 miles of field diversions will be constructed to intercept and route runoff water to selected points to prevent further damage to severely eroded areas, or to protect valuable cropland or other high-damage areas. In some cases a field diversion may be used as the top terrace in a terrace system.

The total cost of installing field diversions is $682,000. The average cost of construction is $264 per mile. The annual cost of maintenance after installation is estimated at three percent of the construction cost.

Cover Crops

Approximately 1,065,219 acres of land require cover crops, green manure crops or legumes as part of a conservation rotation. It is expected

that one-third of this acreage will be planted to such crops each year. Lime and fertilizer will be used in sufficient amounts to assure a satisfactory cover. These crops will protect the soil from erosion and will increase the organic content of the soil.

The total cost of establishing cover crops, green manure crops and legumes is estimated at $6,405,000. The average cost of establishing these crops is estimated at $6.00 per acre. No maintenance costs after installation were used, since it is expected that the use of these crops will become a part of the regular farm operation.

Contour Cultivation

Contour cultivation is of primary importance in a program of erosion control and water conservation. It will be used in conjunction with all terraces and strip crops on all cropland in the watershed.

An additional 10,900 acres of land not requiring terraces or strip crops will be cultivated on the contour. The cost of this contour cultivation alone is estimated at $0.60 per acre, or a total of $6,540.

This practice should become a part of normal farm operations, and be carried out, after installation, at no added cost to the operator.

Strip Crops

Approximately 105,300 acres of cropland, consisting of deep, coarse sands, are seriously affected by wind erosion and need protection by strip crops. Strips of erosion resisting crops, alternated with the erosion-permitting crops, assist materially in reducing erosion by wind and water. Other measures needed on this type of land include soil-improving green manure crops and stubble mulch tillage. After establishment, it is expected that strip cropping will become a part of normal farm operations.

The total cost of establishing strip crops is estimated at $86,000; the average cost per acre is $0.82.

Liming Grasses and Legumes

Approximately 112,000 acres of land in the watershed are acid soils which require the application of agricultural limestone in the establishment of grasses and legumes. A portion of this land is idle and will require lime where grasses and legumes are to be seeded for the establishment of permanent grassland. The remainder of this acreage is in cropland and will require lime for the establishment of the legume portion of the conservation rotation.

The application of lime to sour soils makes possible the growth of legumes, which fix the nitrogen essential to vigorous root growth and foliage development. These legumes, either in permanent grassland or cropland, will build up the soil fertility (or at least counteract soil fertility losses by crop removal), maintain organic matter content, and improve soil structure. All of these effects are important in the improvement of watershed conditions.

The total cost of applying limestone is estimated at $840,600, or an average per-acre cost of $7.50.

Fertilizing Grasses and Legumes

Fertilizer will be needed on approximately 541,000 acres of openland for the establishment of grasses and legumes. Part of this land is being converted from idle land to permanent grassland, and the remainder is cropland needing fertilizer for the establishment of the legume portion of the conservation rotation. Only that amount of fertilizer necessary for the successful establishment of cover is included in this practice.

The total estimated cost of applying fertilizer is $4,726,000, or about $8.75 per acre. Recurring and continuing costs after the initial application of lime and fertilizer have been included under "Increased Operating Cost to Landowners".

Seeding Grassland

Development of permanent grassland on land converted from crop and idle land is essential in the overall watershed plan of improvement. Seedings of adapted grasses and legumes are needed along with sufficient lime and fertilizer to assure a satisfactory stand. In the lower portion of the watershed bermuda may be used as a base grass in the establishment of new grassland.

Present grazing land is stocked far in excess of its safe carrying capacity. As a consequence, in some areas the better grasses have been grazed out and have been replaced by less desirable species. Such areas require clearing of brush and overseeding of adapted perennial grasses, with accompanying reduction in stocking rates and regulation of grazing, in order to allow the grasses to become established.

Approximately 235,000 acres of cropland, idle land, over-grazed grassland and blackjack-post oak savanna will be seeded to grasses and legumes under the recommended modified program. The total cost is estimated at $1,522,000 or about $6.50 per acre. The annual cost of maintenance after the initial establishment is included in the item "Increased Operating Cost to Landowners".

see table 26

yes see table #23

Fencing New Grassland

It is estimated that approximately 1,137 miles of new fence will be required for the fencing of future grazing land. The cost is estimated at $500 per mile, or a total cost of $568,500. The annual cost of maintenance after installation is estimated at five percent of the construction cost.

Gully Control

There are some 86,500 acres of gullied grassland in the watershed that require treatment over and above that normally given grassland.

This treatment may consist of plowing in the gully sides, building of small earth plugs, the use of brush, and other measures used locally.

The total cost of gully control is estimated at $586,000, or about $6.77 per acre affected. The annual cost of maintenance is estimated at three percent of the installation cost.

Improved Fire Protection

Improved fire protection will be provided for an additional 420,630 acres of land with a tree cover of blackjack and post oak, located in the southeastern half of the watershed. The objective will be to limit the annual burn to 1.0 percent or less of the protected area. At the present time 71,370 acres in Marshall and Johnston Counties are receiving organized fire protection.

An extensive type of fire protection is recommended. This involves organized cooperative action on the part of the farmers and ranchers in detection and suppression of fires. It requires a minimum of full time personnel for organizing, training and assisting the volunteer groups. Fire fighting tools and equipment will be provided at public expense.

The success of the fire protection program depends on local support and participation in fire prevention and control. A fire prevention educational campaign which will command the backing of civic organizations is of high priority and is provided for in the estimates of costs. Individual contacts by technicians in carrying out other phases of the program will also accomplish much in acquainting the people with the need for preventing and suppressing fires.

The Federal Government will bear up to 75 percent of the cost of installing, operating, and maintaining the fire protection system on private land during the installation period. The remaining 25 percent will be borne by the State, with such local or private contributions as may be available. The State will be encouraged to participate to the fullest extent so that Federal participation can be reduced to about 50 percent by the end of the installation period.

Installation cost for the protection of the blackjack-post oak savanna consists chiefly of furnishing fire-fighting tools and equipment. It is

estimated at two cents per acre, or a total of $8,413, of which $6,310 is a Federal cost.

The total cost of operation and maintenance during the 15-year installation period amounts to about $94,055, or an average annual cost of 1.5 cents per acre. The Federal cost will be approximately $70,500.

The annual operation and maintenance cost after the installation period will be about 1.72 cents per acre, or a total of $7,235. The annual Federal share of this will be $3,618.

Other practices which will be used in the blackjack and post oak areas include: clearing of underbrush, grazing management, cover improvement, seeding of sparsely grassed areas and fencing.

Public Acquisition

Improper land use and the resulting accelerated erosion has reduced the productivity of 772,000 acres of land in the watershed to such an extent that farming has become unprofitable. Much of this land has been abandoned, and the improvements either moved or destroyed. This land is scattered throughout the watershed, but there are two areas in which the eroded and abandoned land is fairly well concentrated. Here the contribution of the land to the flood problem and the economic conditions of the farmers justify the recommendation of land purchase in the interest of flood control.

One of these areas is located in Roger Mills County where the farm units are relatively small. This area is already an authorized public purchase area, under the designation of OK-LU-22, Roger Mills Land Utilization Project, in which 30,968 acres have been acquired by the Federal Government to date. The other part of the watershed where land purchase is recommended is the severely eroded area in the vicinity of Grady, Garvin, and Murray counties. Here extremely heavy abandonment of land has already occurred.

A total of 328,100 acres of land is recommended for public acquisition. It is contemplated that the land will be acquired only through voluntary sales, and that Federal acquisition will be contingent on obtaining such consent of State and local governments as may be required by law.

The total cost of acquisition is estimated at $3,935,463, as follows:

Cost of land, 328,100 acres @ $9.75	$3,198,975
Costs associated with land purchase	503,988 ?
Cost of relocating 775 families @ $300 each	232,500
Total	$3,935,463

Since State and local participation cannot be reliably estimated, the cost of acquisition has been shown in this report as wholly a Federal charge. To the extent that the State or local governments assume responsibility for parts of the acquisition program, the need for Federal financing will be reduced.

Development and Management of Acquired Land

Measures for retarding runoff and preventing soil erosion will be installed on the severely eroded purchased land in accordance with its needs and capabilities. Since severely eroded soils characterize the farms to be purchased, large areas will be converted to grassland. The emphasis will be placed, therefore, on such measures as seeding, sodding, fencing, proper management and fire protection.

It is proposed that lands acquired will, after development, be leased to local farmers for grazing purposes. Leases will be of such a nature as to assure proper grazing management. Leaseholders will be expected to follow a sound conservation program on their privately-owned land as part of the consideration for the leasing of Federal land.

The total estimated cost of development and management of acquired land is $2,527,990. This is an average cost of $7.70 per acre. After development of land is complete it is estimated that $65,620 annually will be required for maintenance.

Farm and Group Waterways

Approximately 2,560 miles of farm and group waterways, including terrace outlets, will be established to reduce sediment yield and land destruction resulting from uncontrolled runoff. Waterways will be stabilized by reshaping if necessary, and by establishment of vegetative cover. Structures needed in conjunction with this measure are included in the grade stabilizing structures as described in the following section.

The total cost of installing farm and group waterways is estimated to be $896,000 based on a construction cost of $350 per mile. The annual cost of maintenance after construction is estimated at five percent of the construction cost.

Grade Stabilizing Structures

Approximately 3,600 permanent type structures are needed to prevent the formation of gullies at the discharge ends of waterways, diversions, and spillways and to arrest the advance of the more active gullies now existing. Included will be drop structures of concrete or masonry, earth dams with drop inlet spillways or vegetated spillways, concrete or masonry chutes and other structures of conventional types. In some cases the desired result can be acheived by altering the inlet or outlet of highway drainage structures. Where this is feasible it will be done. Where topography permits the earth dams with drop inlet spillways will be designed to detain flood water thereby reducing the rate of outflow.

The specific type of structure, its construction, size and cost, will vary with the individual site condition and the problems of that particular location. On the larger entrenched drainageways the cost per structure may run as high as $2,500; on the smaller structures the cost may be as low as $150 to $200.

The total cost of the 3,600 grade stabilizing structures is estimated to be $2,520,000, or an average of $700 per structure.

It is estimated that about one-eighth of these structures will be built to reduce erosion along county or state highways.

The annual maintenance cost is estimated to be three percent of the construction cost.

Educational Assistance

Landowners and operators will be furnished educational assistance to facilitate installation of the recommended modified program. They will be supplied information as to the manner in which services and assistance are made available through the various governmental agencies, and how they, through their own efforts, may contribute most economically to the success of the program. Intensified educational efforts will be directed to

familarizing farmers with the recommended practices and measures, how to install and apply measures not requiring technical services, and how to maintain such measures. The cost of educational assistance on a subwatershed basis for the 15-year installation period is estimated at $711,000.

Technical Services

Technical services will be made available to landowners and operators for planning and applying the necessary land use adjustments, for planning and applying conservation practices and measures, and for integrating this work with other measures included in the recommended modified program. The cost of furnishing these services for the installation period is estimated to be $1,843,000.

Administration of Direct Aids

The recommended modified program includes the payment of direct aids to individual landowners and operators by the Federal Government to defray portions of the cost of certain measures. The estimated cost of direct aids is based on present rates of payment per unit. Payment for the units included in the recommended modified program would, therefore, occur during the 15-year installation period and would not duplicate payments made under the going programs. The cost of administering these direct aids is approximately five percent of the payments, and amounts to $676,610 for the 15-year installation period.

Facilitating Measuring Devices

It is recommended that measuring devices be installed on one large representative subwatershed, and on selected segments of at least two others. The purpose of these installations is to obtain quantitative information on rainfall and runoff, and sediment loads of streams, in order to facilitate installation of the recommended modified program. The measurements should include the following:

a. Measurement of the total quantity and quality of waterflow, base flow, bank storage, groundwater recharge, rate of return of groundwater to the stream, and sediment loads in streams.

b. Measurement of precipitation and determination of rainfall-runoff relationship.

c. Determination of floodwater hydrographs in drainage areas up to 100 square miles in extent to assist in the routing of floods, and in the design of remedial measures.

Additional information is needed on the effects of land treatment practices on runoff and water yield in watersheds of this size. Present rain gages do not give a clear picture of the rainfall pattern; river gages are in operation only on the large streams, and are useful only as checks on hydrologic evaluations.

Determinations of the rainfall-runoff relationship in tributary watersheds have been based on a rainfall pattern established by the nearest gage or gages, high water marks, channel and flood plain surveys, and computed hydrograph relationships. A more detailed measurement of rainfall and runoff in tributary watersheds needs to be made to provide improved design information to facilitate installation of the recommended modified program.

A review of present information was made in cooperation with the U. S. Geological Survey and a plan evolved for collecting hydrologic data for improvement of the design of floodwater retarding and erosion prevention measures. The data obtained also would be useful in measuring more accurately the quantitative effects of the recommended modified program.

Wherever possible, gages will be located at sites recommended by the subcommittee on Hydrologic Data of the Federal Inter-Agency River Basin Committee. Final location of the areas to be measured will be determined only after adequate surveys have been made.

It is recommended that one tributary area of approximately 100 square miles be selected for intensive gaging. A network of recording and

standard rain gages will be located on this watershed to collect detailed rainfall information for correlation with runoff; water level recorders will be placed on selected floodwater retarding structures; and water stage recorders on the tributary main stem at selected points. Sediment sampling stations will be maintained at a few gages to secure information regarding the sediment losses from small drainage areas. On several selected floodwater retarding structures detailed cross-sections will be run periodically in order to determine the sediment output per square mile of drainage area.

It is also recommended that two or three additional tributary watersheds be gaged less intensively.

The total cost of installing the measuring devices is estimated at $61,800, as shown in table 27.

The U. S. Geological Survey will operate and maintain the water stage and water level recorders, and the Soil Conservation Service will operate and maintain the rain gages. The Geological Survey will compile and analyze data from all gages. It is estimated that the total annual costs of maintenance and operation will be $20,000.

Table 27. Estimated Cost of Installation of Measuring Devices

Washita River Watershed

Type of Measuring Device	Number Needed	Unit Cost (Dollars)	Total Cost (Dollars)
Water Stage Recorder	28	1,500	42,000
Recording Rain Gage	30	300	9,000
Standard Rain Gage	52	100	5,200
Cost of Installation			56,200
Geologic and Location Surveys			5,600
Total Cost			61,800

INDEPENDENT MEASURES

Floodwater Retarding Structures and Appurtenances

Detailed investigations of the need for and feasibility of floodwater retarding structures and appurtenances were made in nine sample tributaries.

In the development of plans for floodwater retarding structures it was found that certain appurtenant structures or measures were necessary for the successful operation of the retarding structure. Such appurtenances consist of floodwater diversions, drop inlets, and floodways. So important are these appurtenant structures or measures that they frequently influence the design of the water retarding structure itself. Since these appurtenances are an integral part of the floodwater retarding structures they were evaluated with the floodwater retarding structures, rather than separately or independently.

Floodwater Retarding Structures: It is estimated that 652 floodwater retarding structures are needed to provide runoff control of 3,085 square miles, with over 957,000 acre-feet of storage. Approximately 42 floodwater retarding structures will be located on Federal land. The drainage area above individual dams usually will vary from two to ten square miles, with from 758 to 2,768 acre-feet detention storage provided.

The dams are planned to be constructed of rolled earth fills with vegetated emergency spillways. The average dam will contain 106,700 cubic yards of earth. The design of the draw down tubes on the retarding structures will provide for the automatic release of water to a predetermined stage and in addition provide an outlet which can be used to release all or most of the storage.

There are approximately 13,286 acres of flood plain inundated by the permanent pools, of which 5,052 acres are cultivated land. Approximately

19,649 acres of flood plain is in the floodwater pools, of which 7,907 acres are cultivated. In addition there are 64,490 acres of upland in the floodwater and permanent pools of which 22,100 acres are cultivated. In calculating loss of net income from this land, no income was figured for the land in the permanent pools after installation of the retarding structures. Cropland in the floodwater pools will be converted to grass and the net income from grazing was calculated for all land in the floodwater pool.

The number and size of floodwater retarding structures by tributary areas is shown in table 28. Figure 6, Appendix III shows the tributary areas in the watershed.

The estimated cost of floodwater retarding structures is shown in table 29. These costs are based on recent actual contract prices for similar structures adjusted to reflect 1949 prices. The cost of construction includes fill, concrete work, steel reinforcing, clearing and grubbing, drainage, spreading of topsoil, sodding, fencing, replacement costs, and any other cost associated with construction. Engineering costs consist of all surveys, including core drilling, design, cartographic work, inspection, and other engineering costs. The contingency cost includes the estimated cost of maintenance and repairs which may be required from the time the structure is completed to the time of its transfer in good condition to the local operating and maintaining agency.

The annual cost of maintenance, both during and after the installation period, is estimated at $200 per completed structure.

Estimated costs are based on the Federal purchase of 216 sites, and private domation of the remaining 436 sites.

<u>Floodwater Diversions:</u> Surveys indicate that 194.4 miles of floodwater diversions are needed in conjunction with floodwater retarding

Table 28 - Number and Size of Floodwater Retarding Structures by Tributary Areas

Washita River Watershed

Tributary Area	No. of Reservoirs	Acre-Feet Flood Storage per Reservoir	Total Acre-Feet Flood Storage	Cu. Yard Fill per Dam	Total Cubic Yards of Fill
3	83	1,284	106,572	152,500	12,657,500
4	135	1,085	146,475	102,000	13,770,000
5	20	2,404	48,080	94,000	1,880,000
6	189	1,561	294,945	130,190	24,606,600
7	95	2,768	262,960	94,840	9,009,800
8	130	758	98,540	58,800	7,644,000
Total	652	-	957,572	-	69,576,900

Table 29 - Cost of Floodwater Retarding Structures

Washita River Watershed

Item	Non-Federal		Federal	Total
	Public	Private		
	(Dollars)	(Dollars)	(Dollars)	(Dollars)
Construction Cost	-	-	25,566,000	25,566,000
Engineering Cost	-	-	2,434,000	2,434,000
Contingency Cost	-	-	3,652,000	3,652,000
Site Cost	-	3,735,000	2,338,000	6,073,000
Maintenance during Installation	-	915,000	63,000	978,000
Total Cost	-	4,650,000	34,053,000	38,703,000

structures; 23.6 miles of these diversions will be located on Federal land. Often these diversions are used to increase the drainage area of reservoirs by diverting outside water to them.

The total cost of floodwater diversions is estimated at $98,800, or about $500 per mile. The annual cost of maintenance, both during and after the installation period, is estimated at $40 per mile.

Drop Inlets: Approximately 417 drop inlets or other drop structures are planned in association with floodwater retarding structures. Approximately 24 of these drop inlets will be located on Federal land. When earth fills are used with the drop inlets, the resulting small detention pools act as settling basins for sediment which would otherwise find its way into the floodwater retarding structure below. The total estimated cost of the drop inlets and other drop structures is $1,554,800, or an average of about $3,700 each.

Is this included in 2nd Pg 11 ?

The annual cost of maintenance, both during and after the installation period, is estimated at $25 per structure.

Floodways: Approximately 91.3 miles of floodways are needed below floodwater retarding structures in order to conduct discharge waters at non-damaging velocities into stabilized tributary or main stem channels. In some instances channel widening is necessary in order to increase channel capacities.

The cost of constructing these floodways is estimated at $183,200, or about $2,000 per mile. The annual cost of maintenance, both during and after the installation period, is estimated at five percent of the construction cost.

APPENDIX VI

PROGRAM APPRAISAL

WASHITA RIVER WATERSHED

The recommended modified program will reduce damage caused by floodwater and sediment, will increase the productive capacity of flood plain lands and will increase the income of land operators. The reductions in damages and increases in production and income are the benefits from the program. The purpose of this appendix is to set forth the monetary evaluations of the benefits accruing from the modified program and components thereof and to compare these benefits with the cost of the modified program or of the applicable component part.

By flood routing methods the annual flood damages were determined for the following conditions:

1. Present.
2. With the going land treatment program installed.
3. With a complete land treatment program installed.
4. With the recommended modified program installed.

FLOODWATER AND SEDIMENT DAMAGE REDUCTION

Reduction in Floodwater Damage

Acres Damaged: In the Washita River Watershed there are approximately 377,000 (@ 60% = $150 per a) acres subject to floodwater and sediment damage. Of this flood plain area 265,000 acres are on tributaries and 112,000 on the main stem. Without the installation of the recommended modified program it is estimated that there will be 466,780 (@60% = $122 per a) acres flooded annually, including replication of acreages flooded more than once during the year. The recommended modified program will reduce the average total acreage flooded each

year to about 184,634 acres, or a reduction of about 60 percent. The frequency and average depth of inundation on the flooded areas will be reduced.

Crops and Pasture: The present average annual damage to crops and pasture is estimated to be $3,136,802. It is expected that the recommended modified program will reduce this damage by $1,977,065, of which $556,731 is from reduction by land treatment measures and $1,420,334 is from reduction by independent measures. Reduction in damage to crops and pasture will be the largest of the flood control benefits, amounting to 58 percent of all benefits derived from reduction in damages caused by floodwater and sediment.

Flood Plain Scour: It is estimated that the recommended modified program will reduce annual scour damage by $62,957, or 58 percent. The benefit from reduction of scour damage is two percent of the total benefits from reduction of flood damages. The land treatment measures will account for $15,983 of this benefit and independent measures $46,974.

Other Agricultural Damage: It is estimated that the recommended modified program will reduce average annual damage to fences, farm buildings, stored crops, equipment, farm roads, livestock, and similar items by $418,843, or 66 percent. Of this benefit $133,858 is from land treatment measures and $284,985 is from independent measures. The benefit from reduction of this damage is 12 percent of the total benefits from reduction of flood damages.

Nonagricultural Damage: The average annual damage to highways, bridges, railroads, industrial developments, urban and other nonagricultural property will be reduced by $378,007, a reduction of 65 percent.

Of the benefit from reduction of nonagricultural damage $126,664 results from land treatment measures and $251,343 from independent measures. This benefit constitutes 11 percent of the total benefits from reduction of flood damages.

Reduction of Sediment Damage

Valley Sedimentation: It is estimated that the recommended modified program will reduce the damage from valley sedimentation by $61,105, of which $20,033 is from land treatment measures and $41,072 is from installation of independent measures. This is a reduction of approximately 47 percent in the present annual damage from this source. The benefit from reduction of valley sedimentation damage is approximately two percent of the total benefit from flood damage reduction.

Reservoir Sedimentation: Benefit from reduction of sediment damage to reservoirs by the recommended modified program is estimated to be $71,931 annually, with $48,777 of the benefit from land treatment measures and $23,154 from independent measures. This benefit represents a reduction of 36 percent in the present damage to reservoirs by sedimentation and constitutes two percent of the total benefits from reduction of flood damages.

Reduction of Indirect Damage

It is estimated that the recommended modified program will reduce indirect damage, interruption of transportation and other services, loss of business in the community, etc., by $416,201 annually, which is a reduction of 63 percent in this type of damage. This flood damage reduction benefit is 12 percent of the total benefits from reduction of flood damages by the recommended modified program.

Table 30 - Summary of Average Annual Benefit from Reduction in Floodwater and Sediment Damages by the Recommended Modified Program - 1949 Prices

Washita River Watershed

Item	Average Annual Benefit		
	Land Treatment Measures	Independent Measures	Recommended Modified Program
	(dollars)	(dollars)	(dollars)
Reduction in Floodwater Damage			
Crops and Pasture	556,731	1,420,334	1,977,065
Flood Plain Scour	15,983	46,974	62,957
Other Agricultural Damage	133,858	284,985	418,843
Nonagricultural Damage	126,664	251,343	378,007
Subtotal	833,236	2,003,636	2,836,872
Reduction in Sediment Damage			
Valley Sediment Deposition	20,033	41,072	61,105
Reservoir Sedimentation	48,777	23,154	71,931
Subtotal	68,810	64,226	133,036
Reduction in Indirect Damage	122,300	293,901	416,201
Total	1,024,346	2,361,763	3,386,109

Summary of Benefits

The total average annual benefit from reduction of floodwater and sediment damage by the recommended modified program is estimated to be \$3,386,109. Of this total benefit from damage reduction \$1,024,346 is from reduction of damages by land treatment measures and \$2,361,763 is from reduction by independent measures. Table 30 shows the average annual benefit from damage reduction by items of damage, for the land treatment measures of the recommended modified program, for the independent measures, and for the total recommended modified program.

INCREASED INCOME FROM THE RECOMMENDED MODIFIED PROGRAM

In addition to the benefit from reduction of floodwater and sediment damage the recommended modified program will increase the productivity of certain flood plain lands and increase or stabilize productivity on other watershed lands.

Intensification of Land Use in Flood Plains

The increase in annual net income from more intensive agricultural use of flood plain lands is estimated to be $910,519. This benefit, as estimated, is due to the installation of the independent measures. Any benefit from this source attributed to land treatment measures, which was not calculated as explained under the procedure for determining benefits from more intensive use of the flood plain, would be over and above this estimated benefit.

Indirect Benefits from Intensified Land Use: Increased production in the protected flood plains will contribute to the economic welfare of nearby communities through increased business, added income to workers in agricultural processing or servicing establishments, and similar ways. This item has not been included in the benefit-cost evaluation.

Conservation Benefits

Reduction in Soil Loss: Using information developed in the Conservation Needs study 1/ and other applicable research data on the effect of conservation practices on soil losses, estimates were made of the present rate of soil loss, the amount that loss would be reduced by the going program, and the further reduction that would be expected from the application of the recommended modified program. These soil losses

1/ Made by the Soil Conservation Service in 1949.

expressed in acre-feet per square mile of drainage area, were calculated by land uses within problem areas in soil conservation. The resulting figures represent a weighted average over the entire watershed, and are as follows:

Watershed Condition	Estimated Annual Rate of Soil Loss, Acre-feet per Sq. Mile
Present Condition	2.17
After application of the going program	1.60
After application of the going and the recommended modified program	.88

The expected reduction in soil loss due to the application of the recommended modified program is therefore 1.60 - .88, or .72 acre-feet per square mile. This represents a reduction in soil loss of 47 percent.

No direct monetary value was placed on this reduction of soil loss since it is taken into account in determining the effect of the recommended modified program on crop and pasture yields.

Crop and Pasture Yields: The effect of the recommended modified program on crop and pasture yields varies by problem areas in soil conservation. Table 31 shows the present yield of the major crops and pasture, and the estimated future yield with the recommended modified program and with the going program only, by problem areas in soil conservation.

Farm Income: Application of the recommended modified program to farm and ranch operating units will result in an average annual benefit of $7,736,751. This figure includes $2,176,405 in receipts from additional livestock, $767,624 in increased receipts from crops due to increases in yields, and $4,792,722 in decreased costs of producing crops as a result of acreage reductions. The annual operating cost, $3,510,663, includes

Table 31 - Estimated Crop and Pasture Yields at Present and Under Future Conditions with Recommended Modified Program and with Going Program 1/ by Problem Areas in Soil Conservation

Washita River Watershed

Crop	Unit	Present Conditions	With Recommended Modified Program	With Going Program Only
		Rolling Red Plains		
Wheat	Bu.	11.7	16.8	13.7
Oats	Bu.	15.6	22.3	17.8
Barley	Bu.	12.1	18.7	14.5
Corn	Bu.	11.7	16.7	14.5
Cotton	Lb. Lint	140.0	204.0	170.0
Grain Sorghum	Bu.	11.0	18.1	14.0
Forage Sorghum	Ton	1.3	1.9	1.6
Alfalfa Hay	Ton	1.24	1.8	1.5
Tame Hay	Ton	1.0	1.4	1.15
Wild Hay	Ton	0.7	0.9	0.8
Pasture	A.U.M.	0.21	0.33	0.27
		Reddish Prairies		
Corn	Bu.	17.9	23.6	20.0
Wheat	Bu.	12.0	14.3	13.1
Cotton	Lb. Lint	184.0	223.0	200.0
Barley	Bu.	14.7	19.8	17.2
Oats	Bu.	19.4	24.2	21.5
Soybeans	Bu.	7.0	8.4	7.6
Cowpeas	Bu.	6.0	7.2	6.5
Grain Sorghum	Bu.	11.9	16.0	13.7
Forage Sorghum	Ton	1.35	1.75	1.50
Alfalfa Hay	Ton	1.5	1.7	1.6
Tame Hay	Ton	1.3	1.6	1.4
Wild Hay	Ton	1.1	1.2	1.15
Pasture	A.U.M.	0.54	0.65	0.58
Blackjack-Post Oak Savanna	A.U.M.	0.27	0.35	0.29

Table 31 (Cont'd.) - Estimated Crop and Pasture Yields at Present and Under Future Conditions with Recommended Modified Program and with Going Program Only 1/ by Problem Areas in Soil Conservation

Washita River Watershed

Crop	Unit	Present Conditions	With Recommended Modified Program	With Going Program Only
		Cross Timbers		
Barley	Bu.	12.1	14.0	13.1
Corn	Bu.	17.1	24.0	19.0
Wheat	Bu.	9.2	12.5	10.1
Oats	Bu.	16.7	21.7	19.0
Cotton	Lb. Lint	158.5	196.5	170.0
Soybeans	Bu.	6.0	7.2	6.6
Cowpeas	Bu.	5.0	6.0	5.5
Peanuts	Lb.	450.0	590.0	490.0
Alfalfa Hay	Ton	1.4	1.8	1.5
Tame Hay	Ton	1.2	1.6	1.3
Wild Hay	Ton	0.9	1.0	0.95
Pasture	A.U.M.	0.47	0.60	0.50
Blackjack-Post Oak Savanna	A.U.M.	0.23	0.33	0.25
		Coastal Plains		
Wheat	Bu.	11.5	12.6	12.1
Oats	Bu.	16.5	20.3	18.0
Corn	Bu.	15.8	18.3	17.1
Cotton	Lb. Lint	134.0	178.0	154.0
Grain Sorghum	Bu.	11.0	12.8	11.9
Forage Sorghum	Ton	1.5	1.9	1.7
Peanuts	Lb.	430.0	542.0	495.0
Alfalfa Hay	Ton	0.6	0.7	0.65
Tame Hay	Ton	1.3	1.56	1.40
Wild Hay	Ton	1.0	1.1	1.05
Pasture	A.U.M.	0.58	0.67	0.60

Table 31 (Cont'd.) - Estimated Crop and Pasture Yields at Present and Under Future Conditions with Recommended Modified Program and with Going Program Only 1/ by Problem Areas in Soil Conservation

Washita River Watershed

Crop	Unit	Present Conditions	With Recommended Modified Program	With Going Program Only
		Grand Prairie		
Oats	Bu.	22.0	29.7	25.3
Wheat	Bu.	10.5	11.6	11.0
Corn	Bu.	20.2	25.2	22.6
Cotton	Lb. Lint	140.0	195.0	162.0
Grain Sorghum	Bu.	15.3	16.8	16.0
Forage Sorghum	Ton	1.4	1.6	1.5
Alfalfa Hay	Ton	1.5	1.7	1.6
Tame Hay	Ton	1.5	1.8	1.6
Wild Hay	Ton	1.3	1.43	1.36
Pasture	A.U.M.	0.52	0.80	0.67
Blackjack-Post Oak Savanna	A.U.M.	0.25	0.32	0.27
		Granitic Soils		
Wheat	Bu.	11.5	12.6	11.9
Oats	Bu.	16.5	20.3	18.0
Corn	Bu.	15.8	18.3	16.5
Grain Sorghum	Bu.	11.0	12.8	11.5
Cotton	Lb. Lint	134.0	161.0	145.0
Forage Sorghum	Ton	1.5	1.9	1.6
Peanuts	Lb.	430.0	516.0	460.0
Alfalfa Hay	Ton	0.6	0.7	0.62
Tame Hay	Ton	1.3	1.56	1.40
Wild Hay	Ton	1.0	1.1	1.02
Pasture	A.U.M.	0.30	0.48	0.36
Blackjack-Post Oak Savanna	A.U.M.	0.15	0.20	0.16

Table 31 (Cont'd.) - Estimated Crop and Pasture Yields at Present and Under Future Conditions with Recommended Modified Program and with Going Program Only 1/ by Problem Areas in Soil Conservation

Washita River Watershed

Crop	Unit	Present Conditions	With Recommended Modified Program	With Going Program Only
		High Plains		
Forage Sorghum	Ton	1.4	1.8	1.6
Grain Sorghum	Bu.	11.3	16.0	13.3
Cotton	Lb. Lint	135.0	185.0	155.0
Barley	Bu.	10.7	14.9	12.6
Corn	Bu.	10.0	11.0	10.5
Oats	Bu.	12.9	16.8	14.7
Wheat	Bu.	11.4	15.0	13.2
Wild Hay	Ton	0.6	0.7	0.65
Pasture	A.U.M.	0.36	0.58	0.46

1/ Estimated yields under the Going Program are based on the ratio between treatment under this program and total treatment needs.

$1,015,081 as the expense associated with producing additional livestock, $3,427 as increased harvesting costs of crops when the total production is increased because of higher yields, and $2,492,155 in decreased income from crops where total production is reduced because of reductions in acreage. In addition, farm and ranch operators will be expected to expend the equivalent of $1,022,850 annually for installation and maintenance of the land treatment measures. It is estimated that the recommended modified program will increase the annual net income of farm and ranch owners and operators by $3,203,238 annually.

LOSS OF NET INCOME

The annual loss of income to landowners and operators in the sites of floodwater retarding structures was determined for each tributary area. Interest at four percent was applied to the estimated acquisition cost of private sites and interest at two and one-half percent to the cost of sites to be publicly acquired. This annual interest charge was subtracted from the annual loss of income to determine the annual loss of net income by tributary areas. The annual loss of net income thus determined was $204,218, (1949 prices) and is included with the costs in table 32.

NON-MONETARY BENEFITS

No values were placed upon indirect and intangible benefits such as increased food and improved shelter for wild fowl and game animals, greater population of fish as a result of clearer streams of more even flow, and improved recreational facilities. Although they are significantly affected by control of floods and are highly important in the economy of the watershed these items are difficult to measure in monetary terms.

Table 32 - Summary and Comparison of Average Annual Costs and Benefits (1949 Prices) of the Recommended Modified Program

Washita River Watershed

Item	Land Treatment Measures	Independent Measures	Total
	(Dollars)	(Dollars)	(Dollars)
Average Annual Costs			
Federal	673,874	1,001,697	1,675,571
Public (other than Federal)	20,136	4,555	24,691
Private	4,533,513	533,791	5,067,304
Total Average Annual Cost	5,227,523	1,540,043	6,767,566
Average Annual Benefit			
Reduction in Floodwater Damage			
Crops and Pasture	556,731	1,420,334	1,977,065
Flood Plain Scour	15,983	46,974	62,957
Other Agricultural	133,858	284,985	418,843
Nonagricultural	126,664	251,343	378,007
Subtotal	833,236	2,003,636	2,836,872
Reduction in Sediment Damage			
Valley Sediment Deposition	20,033	41,072	61,105
Reservoir Sedimentation	48,777	23,154	71,931
Subtotal	68,810	64,226	133,036
Reduction in Indirect Damage	122,300	293,901	416,201
Increased Income from Flood Plain Lands	-	910,519	910,519
Conservation Benefit	7,736,751	-	7,736,751
Total Average Annual Benefit	8,761,097	3,272,282	12,033,379
Benefit-Cost Ratio	1.68:1	2.12:1	1.78:1

COMPARISON OF BENEFITS AND COSTS

The average annual cost of the recommended modified program is $6,767,566, at 1949 prices. Installation costs of the recommended modified program, other than the cost of floodwater retarding structures and appurtenances, were converted to annual costs by using a two and one-half percent interest rate for public costs and a four percent interest rate for private costs. The installation cost of the independent measures was amortized over a hundred year period using the same interest rates as above. Average annual costs of the recommended modified program by items are given in table 25, Appendix V.

At 1949 prices the average annual benefit from the recommended modified program will be $12,033,379, of which $7,736,751 will be conservation benefits to landowners and operators. The costs and benefits are summarized by items of benefit and costs of groups of measures for the watershed in table 32. The average annual costs and benefits of the independent measures by tributary areas are shown in table 33.

Comparison of Average Annual Benefits and Cost

Estimates of damages, benefits and costs of the recommended modified program have been made on the basis of 1949 prices, the latest full calendar year for which prices were available. For the purpose of comparing benefits and costs at a predicted normal the factors shown in table 34 were used. In all comparisons, capital charges have been converted to their annual equivalents by the use of 2.5 percent interest rates for public and 4 percent for private charges.

Under normal prices the ratio of benefit to cost for the entire recommended modified program is 1.76 to 1. The benefit-cost ratio for the land treatment measures is 1.68 to 1, and for the independent

Table 33 - Annual Cost and Benefit of Independent Measures, 1949 and Normal Prices by Tributary Areas

Washita River Watershed

Tributary Areas 2/	Annual Benefits 1/ 1949 Prices	Annual Benefits 1/ Normal Prices	Annual Costs 1949 Prices	Annual Costs Normal Prices	Benefit Cost-Ratio 1949 Prices	Benefit Cost-Ratio Normal Prices
	(Dollars)	(Dollars)	(Dollars)	(Dollars)		
1	-	-	-	-	-	-
2	-	-	-	-	-	-
3	436,748	271,768	226,675	151,565	1.93	1.79
4	728,417	447,844	272,095	179,841	2.68	2.49
5	170,870	105,417	53,661	34,531	3.18	3.05
6	973,263	600,675	517,076	339,533	1.88	1.77
7	703,432	433,386	270,787	172,737	2.60	2.51
8	259,552	159,030	199,749	129,906	1.30	1.22
9	-	-	-	-	-	-
Total	3,272,282	2,018,120	1,540,043	1,008,113	2.12	2.00

1/ Benefits from floodwater and sediment damage reductions on the main stem were allocated to tributary areas by the use of factors, for each main stem reach, based on drainage area and percent of control.

2/ For location of tributary areas see figure 6, Appendix III.

measures it is 2.00 to 1. The costs of the measures by groups of measures and the benefits by types and source of benefits, based on normal prices, are shown in table 35. The annual costs and benefits, based on 1949 and normal prices, for the independent measures and the benefit-cost ratios by tributary areas are shown in table 33.

Comparison of the Effect of Discounting Delayed Benefits and Costs

Certain types of benefits and costs resulting from the recommended modified program will be delayed until treatment measures become fully effective. In this analysis, therefore, such benefits and costs were discounted to allow for this lag in effectiveness.

Table 34 - Factors Used in Converting Costs and Benefits to a Predicted Normal or Intermediate Level

Washita River Watershed

Name of Index from Which Factor was Derived	Factor	Item of Cost or Benefit
Prices received by farmers	.602	Reduction of crop and pasture damage Increased farm receipts (benefit) Decreased farm receipts (cost) Reduction in flood plain scour Reduction in valley sedimentation (main stem) Land enhancement Land acquisition cost Cost of sites for floodwater retarding structures Negative project benefits
Prices paid by farmers	.651	Reduction of other agricultural damage Increased farm expenses (cost) Decreased farm expenses (benefit) Federal and public costs of the land treatment measures with the exception of construction costs Private costs of installing and maintaining the recommended program Reduction of valley sediment (Tributaries)
Wage rate	.643	Reduction in indirect damage
Wage rates	.821 1/	Technical services, administration of direct aids, and other federal salaries and travel expense
Construction Costs	.681	Reduction in nonagricultural damage Construction costs of the recommended program Reduction of Sediment damage to reservoirs

1/ This represents one-half of the predicted decline in wage rates.

Table 35 - Summary and Comparison of Average Annual Costs and Benefits (Normal Prices) of the Recommended Modified Program

Washita River Watershed

Item	Land Treatment Measures	Independent Measures	Total
	(Dollars)	(Dollars)	(Dollars)
Average Annual Costs			
Federal	449,378	663,724	1,113,102
Public	15,128	3,067	18,195
Private	2,829,201	341,322	3,170,523
Total Average Annual Cost	3,293,707	1,008,113	4,301,820
Average Annual Benefit			
Reduction in Floodwater Damage			
Crops and Pasture	335,152	855,041	1,190,193
Flood Plain Scour	9,622	28,278	37,900
Other Agricultural	87,142	185,525	272,667
Nonagricultural	86,258	171,167	257,425
Subtotal	518,174	1,240,011	1,758,185
Reduction in Sediment Damage			
Valley Sediment Deposition	12,364	25,231	37,595
Reservoir Sedimentation	33,217	15,768	48,985
Subtotal	45,581	40,999	86,580
Reduction in Indirect Damage	78,639	188,978	267,617
Increased Income from Flood Plain Lands	-	548,132	548,132
Conservation Benefit	4,892,368	-	4,892,368
Total Average Annual Benefit	5,534,762	2,018,120	7,552,882
Benefit-Cost Ratio	1.68:1	2.00:1	1.76:1

It was assumed that floodwater damage reductions from the land treatment measures, benefits from intensified use of flood plains, and conservation benefits would, on an average, be delayed five years. A similar delay would be applicable to farm and ranch operating costs. It was also assumed that each of these benefits and costs would start at zero and build up uniformly to the maximum over the period of delay. They would then level off and remain constant thereafter.

Benefits from reductions in damage resulting from the installation of the independent measure will become fully effective upon installation and, therefore, were not discounted.

Discounting deferred benefits and costs of the land treatment measures would reduce their benefit-cost ratio (normal prices) from 1.68:1 to 1.64:1. The benefit-cost ratio for the independent measures would be reduced from 2.00:1 to 1.98:1 and the benefit-cost ratio for the recommended modified program would be reduced from 1.76:1 to 1.72:1.

Evaluation of Independent Measures in Other Areas

An evaluation of the effects of the independent measures was made for each of the tributary areas. For those tributary areas, in table 33, for which costs and benefits are not shown, the benefit-cost ratios were unfavorable and independent measures not recommended at this time. This does not eliminate, however, the possibility that detailed investigations of individual tributary watersheds prior to initiating the installation of land treatment measures may show that independent measures may be justified in parts of the tributary areas where they were not found feasible at this time.

PROCEDURE FOR DETERMINING THE BENEFIT FROM INTENSIFIED USE OF THE FLOOD PLAIN

It is expected that bottomland areas will be used more intensively as the recommended independent measures are installed. This will be made possible by the reduction in extent and frequency of flooding resulting from the recommended independent measures.

Investigations were made of the effect on land use in flood plain areas protected by floodwater retarding structures. These investigations indicated that land use changes will be made in the areas receiving a high degree of protection from flooding. Therefore, benefit from more intensive land use in the flood plains was estimated only for those flood plain areas receiving a high degree of protection from flooding by the independent measures.

Detailed investigations of sample areas were made to determine present land use, yields of major crops, and the areas not now in cultivation that are physically capable of cultivation. Farm operators in the flood plains were contacted to determine the percent of land physically capable of cultivation that would be cultivated, the distribution of crops on the land going to cultivation, and any changes in crop distribtuion on the land now in cultivation. Small inaccessible tracts of land, though physically capable of being cultivated, were not considered suitable for cultivation. No changes were made in the crop yields or acres of improved pasture in the flood plain.

In the calculation of benefits the average annual gross value of the production in the area protected was determined both for present land use and for future conditions. Costs of production based on Experiment Station data, including all machinery expense, labor (whether

performed by the operator and his family or hired labor) and an added charge for taxes and overhead, were deducted from the gross return to give a net increase in value of production. The expected annual damage to the increased production from the floods remaining after installation of the recommended modified program, was deducted from the net income to arrive at the net benefit. Table 36 illustrates the procedure for the Mill Creek sample tributary.

METHOD OF DETERMINING CONSERVATION BENEFITS

Land treatment measures of the recommended modified program will be applied to agricultural lands of the Washita River Watershed. With more than ninety-six percent of the total drainage area operated under an agricultural economy as farms and ranches, it is important that consideration be given to the effect that such a program will have on agricultural income. Crop and livestock production and agricultural income were compared for each problem area in soil conservation under future conditions with the recommended modified program, and under future conditions with the going program only, to evaluate the effect of the recommended modified program.

Differences in income and expense shown by this analysis, plus the cost of installation and maintenance of measures, served as a basis for determining the conservation benefit and cost of the recommended modified program. Within any given problem area in soil conservation an increase in gross income or a reduction in expense with the recommended modified program, over such income or expense with only the going land treatment program, was regarded as a benefit. If application of the recommended modified program would result in reduced gross income or increased expense, the item was classed as a cost.

Table 36 - Increased Annual Income Through More Intensive Use of Protected Flood Plain Land, in Dollars (1949 Prices) - Mill Creek Sample Tributary

Washita River Watershed

Item	Acres	Gross Value of Production	Costs	Net Return	Net Increase in Income
Present Land Use					
Corn	474	17,775	9,504		
Cotton	161	13,202	7,285		
Alfalfa	212	13,788	7,028		
Peanuts	63	4,498	1,710		
Meadow	95	2,492	1,318		
Grain Sorghum	213	6,083	2,961		
Oats	249	5,109	3,274		
Pasture	1,633	4,844 1/	816 1/		
Idle Cropland	849	917 1/	255 1/		
Taxes and Overhead 2/	(1,467)	-	4,078		
Total	3,949	68,708	38,229	30,479	
Future Land Use					
Corn	565	21,188	11,238		
Cotton	158	12,956	7,150		
Alfalfa	652	42,406	21,614		
Peanuts	43	3,070	1,167		
Meadow	114	2,990	1,581		
Grain Sorghum	351	10,025	4,879		
Oats	419	8,598	5,510		
Pasture	1,442	4,283	721		
Idle Cropland	205	221	62		
Taxes and Overhead	(2,302)	-	5,755		
Total	3,949	105,737	59,767	45,970	15,491
Flood Damage on Added Production					1,055
Net Annual Benefit					14,436

1/ The gross value of grazing on pasture and idle cropland is net income except that it contains the cost of taxes, fencing material etc. which was figured at $.50 per acre for pasture and $.30 per acre for idle cropland and shown under costs.

2/ Taxes and overhead are calculated at $2.50 per acre on cultivated land only.

Program Effect on Crop and Pasture Yields

Determination of the effect of recommended measures upon crop and pasture yields was necessary in estimating the conservation benefit and cost of the program. Shifts in some cropland acreages, along with improved seed varieties, mechanization and selection of soil improving practices, have obscured trends in crop yields caused by continuous cropping. Selection of the more productive lands for cash crop production, and the retirement of poorer lands from use for crops, have so affected the average yields that the ordinary use of yield trends gives a distorted view of the effect of soil loss on yields.

Present and Future Yields without Land Treatment Measures: Results from the soil decline study conducted by the Soil Conservation Service were used to determine the effect of continued crop production under present cultural practices. A close relationship is recognized to exist between capability classes and crop-producing ability of the remaining soil. It was assumed that declining productivity was proportionate to rate of soil loss, as this loss is a measure of reduction in the average capability of the land for crop production.

Present crop yields were determined by field investigations within the various problem areas in soil conservation from data supplied by agricultural field technicians.[1/]

These present yields were used as a starting point for determining yield trends in the future without a program. Data from above-mentioned studies of the Soil Conservation Service, supplemented by available studies of soil loss rates on untreated lands, were the basis for estimating yields in the various problem areas in soil conservation.

1/ Effects of Soil Conservation Practices on Production, Region IV; Soil Conservation Service, U. S. Dept. Agri., Fort Worth, Texas.

The assumption was made that yields would remain constant after 15 years. It was recognized that some soil loss and accompanying yield decline would continue after the 15-year period, but the use of this period of time was believed to result in conservative evaluations of the benefits from application of the proposed measures.

Future Yields with Land Treatment: Historical yield records representing farm and ranch units in soil conservation districts on which conservation measures had been applied were used in determining the estimated yield. These records, covering from two to six years, indicated what might be expected after application of land treatment measures. The effect that superior management may have had in yield increases was minimized by adjustment in cases where yields appeared to be unusually high.

The percent of yield increase shown by these records should be attained within approximately five years after application of the land treatment measures, and most measures should have reached their maximum effectiveness by this time. By applying the percent of increase to present yields, the yields to be expected after treatment were determined.

Future Yields with the Going Land Treatment Program: The amount of land treatment measures that would be applied by the end of the installation period was based on the present rate of application (the going program) plus the amount of measures applied at the present. The percentage of application of the various land treatment measures was used as a basis for estimating the percentage of yield change resulting from the complete land treatment program that is attributable to the going program.

Program Effect on Agricultural Production and Income

The impact of the recommended modified program upon the agricultural economy of the watershed was determined by analyzing the effect of such a program in each problem area in soil conservation. With the problem area in soil conservation as an evaluation unit, counties and other civil divisions, located entirely or in the main within a given problem area, were used as sample units. Problem areas located in both states were evaluated by states.

Changes in agricultural income were calculated for each problem area in soil conservation. Information used in making this calculation was:

1. Unit production for the various crops and the beef enterprise in each area.
2. Production expenses, including overhead costs, that would be affected by the recommended modified program.
3. The production of agricultural commodities.
4. Current prices (1949) for all products sold, table 37.

Determination of Crop and Livestock Organization: Census data for crop organization were tabulated and totaled for all sample units in each problem area in soil conservation. From this, the percentage of cropland used for each crop was calculated for each problem area in soil conservation. Carrying capacities of pastures were translated into numbers of beef cows.

Determination of Agricultural Production Without Land Treatment Measures: Since future use of cropland and future livestock numbers in each problem area in soil conservation, both with and without treatment, are important in budgetary analysis the present cropland use and

Table 37 - Agricultural Prices - 1949 1/

Washita River Watershed

Item	Unit	Price
		(Dollars)
Wheat	Bu.	1.91
Corn	Bu.	1.25
Oats	Bu.	0.76
Grain Sorghum	Cwt.	2.04
Cotton Lint	Lb.	0.282
Cotton Seed	Ton	54.54
Hay,Tame,Baled	Ton	17.49
Hay, Alfalfa, Baled	Ton	21.68
Hay, Wild, Baled	Ton	11.98
Peanuts	Lb.	0.102
Soybeans	Bu.	2.22
Hogs	Cwt.	18.71
Beef Cattle	Cwt.	19.02
Veal Calves	Cwt.	21.57
Sheep	Cwt.	9.46
Lambs	Cwt.	22.94
Milch Cows	Per Head	149.92
Butterfat	Lb.	0.55
Wool	Lb.	0.376

1/ Agricultural Prices, BAE, U. S. Dept. of Agriculture.

livestock numbers were adjusted for future conditions. The present use of cropland was assumed to remain the same in the future without land treatment, but any expected changes in crop yields were considered in the analysis. In general, crop and pasture yields are expected to decline in the future without treatment and the quantity of crops and number of livestock carried were reduced in proportion.

Determination of Agricultural Production With Land Treatment Measures: Land use capability classes were used as a basis for determining land use with treatment. The conversion of present cropland to pasture for each problem area in soil conservation was attained by converting present idle cropland to pasture and then converting proportionately the present acreage in various crops if the acreage in idle cropland was not sufficiently large to take care of the expected conversion.

The number of livestock under future conditions with treatment was determined by dividing the safe stocking rates into the total acres of pasture. This determined the number of animal units to be carried on permanent pasture and to this was added the number to be carried on tame and supplemental pasture.

Income Changes: Income for the future, with the going program and with the recommended modified program, was calculated as follows:

1. Crop yields were applied to acres in specified crop use to determine total production.
2. Livestock production per unit was applied to livestock numbers to ascertain total production of livestock.
3. Current prices were applied to all products where there was a change in quantity produced.

4. Where there was a change in quantity produced, in overhead costs, or in production expense, production expense factors were applied to each product.

5. Changes in income and expenses were summarized for each enterprise to obtain gross and net changes in income and expense.

The annual benefit (increased income and reduced expense) and the annual cost (increased expense and decreased income) by problem areas in soil conservation is shown in table 38. The annual net benefit of the recommended land treatment program, considering the annual equivalent cost to farm owners and operators of installing and maintaining the recommended modified program, is given under "Farm Income", page 120 of this appendix.

Table 38 - Average Annual Increased Operating Costs to Farm Owners and Operators and Conservation Benefits from the Recommended Land Treatment Program, by Problem Areas in Soil Conservation, 1949 Prices

Washita River Watershed

Problem Areas in Soil Conservation	Annual Benefit 1/	Annual Cost 2/	Benefit Minus Cost 3/
	(Dollars)	(Dollars)	(Dollars)
High Plains	20,868	3,427	17,058
Rolling Red Plains (Texas)	306,090	129,156	176,934
Rolling Red Plains (Okla.)	2,700,209	238,544	2,461,665
Reddish Prairies	1,775,764	808,880	966,884
Cross Timbers	1,899,366	1,767,758	131,608
Granitic Soils	307,387	251,740	55,647
Grand Prairie	628,805	252,229	376,576
Coastal Plains	98,262	58,546	39,716
Total	7,736,751	3,510,663	4,226,088

1/ Increased income or decreased cost to farm owners and operators.

2/ Increased cost or decreased income to farm owners and operators.

3/ To determine the net annual benefit the annual maintenance and installation cost to farm owners and operators would have to be subtracted, see "Farm Income" page 120.